JULY 1983

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

Assessing the Social Costs of Oil Spills:

The AMOCO CADIZ Case Study

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U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
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National Ocean Service
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NOTICE

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FOREWORD

The Amoco Cadiz oil spill represents a class of events that can have substantial adverse effects on valuable coastal and ocean resources. Oil tanker traffic, offshore oil and gas production and transportation, the transport of hazardous cargoes by vessels, ocean disposal of various types of wastes including dredged materials, and the development and use of the coastal zone for industrial, commercial, residential, and recreational purposes all pose the possibility of damage to coastal and marine ecosystems. Management of coastal and ocean resources should be based on the best possible understanding of the physical, biological, and economic effects of human activities on such systems.

NOAA's scientific and damage assessment responsibilities, with respect to the management of these resources, should be viewed in terms of three increasingly broad perspectives. These same perspectives are relevant to other federal agencies, state agencies, and domestic and international standard setting organizations with ocean resource management responsibilities.

The first is the direct responsibility for determining amounts which can justifiably be paid as compensation to individuals and entities for damages incurred as a result of spills of oil or hazardous substances in U.S. waters. In response to the possibility of oil spills from outer continental shelf oil and gas activities, the Offshore Oil Spill Pollution Fund was established under the Outer Continental Shelf Lands Act Amendments of 1978 (Public Law 95–372). Similarly, in relation to the possibility of damaging spills from hazardous materials (not including oil), a "Superfund" was established under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 (Public Law 96–510). It provides compensation for cleanup and certain other categories of damages, including those to natural resources, from a fund containing up to $1.6 billion. The Offshore Oil Spill Pollution Fund, in the amount of $200 million, provides compensation—in relation to oil spills—for cleanup costs, damages to property, damages to natural resources, losses of profits and earnings, and losses in tax revenues for a period of up to one year. Provisions for at least partial compensation for damages from oil spills is also provided under the Trans-Alaska Pipeline Act of 1973, the Deepwater Port Act of 1974, and the Federal Water Pollution Control Act Amendments of 1977.

A second perspective, again one which involves the planning and operational responsibilities of several federal and state agencies, is the development of spill damage reduction programs. Certain preparations can be made, e.g., in terms of contingency plans and standby equipment and materials, which could mitigate the adverse effects of spills when they occur. However, maintenance of these programs requires the expenditure of resources which could be used to produce other goods and services desired by society. Given the random nature of spills, one part of the problem in developing a spill damage reduction program—as in a flood damage reduction program—is to determine how much of what types of equipment and materials to have ready for emergency use. The key question which must be asked is whether the expected benefits of a particular damage reduction program are sufficient to justify the costs which will be incurred if it is implemented.

The third perspective is the development of management strategies for intensely used ocean regions. Overall management responsibility for inland transportation routes, the Great Lakes, coastal regions, and offshore areas are now shared by a number of federal and state agencies, working through a variety of means to assure interagency cooperation and coordination. In general, any given ocean region can provide various goods and services. The management problem entails making a determination of the optimal mix to produce over time, e.g., that mix which maximizes the present value of the net benefits to society. To make that determination requires information on the probability of spills of different materials, on the damages resulting from such spills, and on the various measures available for reducing damages and the costs of implementing them.

With respect to the first two responsibilities, NOAA represents the Department of Commerce on the National Response Team of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), now revised to implement provisions of CERCLA. NOAA has traditionally provided scientific support and advice to the U.S. Coast Guard, the Federal On-Scene Coordina-

tor for spills into the marine environment. In addition to this responsibility, the revised NCP designates the Secretary of Commerce as the federal "trustee" of "...resources of any kind lying in or under U.S. waters that are navigable by deep draft vessels, including waters of the contiguous zone and parts of the high seas to which the National Contingency Plan is applicable, and other waters subject to tidal influence, and upland areas serving as habitat for marine mammals and other species subject to the protective jurisdiction of NOAA."

Section 301(c)(1) of CERCLA requires the federal government to promulgate regulations no later than December 12, 1982, for the assessment of damages for injury to, destruction of, or loss of natural resources resulting from a release of oil or a hazardous substance. These regulations are to specify: "(A) standard procedures for simplified assessments requiring minimal field observation, including establishing measures of damages based on units of discharge or release or units of affected area, and (B) alternative protocols for conducting assessments in individual cases to determine the type and extent of short- and long-term injury, destruction, or loss. Such regulations shall identify the best available procedures to determine such damages, including both direct and indirect injury, destruction, or loss and shall take into consideration factors including, but not limited to, replacement value, use value, and ability of the ecosystem or resource to recover."

This report describes what is believed to be the most comprehensive economic damage assessment of a major marine pollution event ever undertaken. It demonstrates the application of many of the available methodologies for assessing economic damages while at the same time showing the current limitations on measuring such damages. Though this event was an oil spill, rather than a spill of a "hazardous substance," similar methods would be used to assess the economic damages resulting from a spill of such materials. The practical lessons learned from carrying out this assessment, as well as its results, should be of particular use as guidance to public agencies and others responsible for developing and implementing a damage assessment capability.

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ABSTRACT

Approximately 30 percent of the oil spilled from the Amoco Cadiz in March 1978 came ashore on the Brittany coast. About 400 kilometers of the coast were directly affected. The remainder of the oil was dispersed at sea or evaporated. The oil had adverse effects on marine resources, such as aquacultured oysters and various species of finfish, on the tourist industry, and on the satisfaction of those who expected to or did recreate on the Brittany coast. The economic damages or losses associated with these adverse physical and biological effects, plus the costs associated with the cleanup effort which began immediately, constitute the economic costs of the oil spill. This report presents, and describes the methods used to estimate the various costs as divided into cleanup costs; losses to marine resources, such as oyster-culturing and open-seas fisheries; losses to recreationists, both tourists and residents; losses to the tourist industry; loss of the tanker and cargo; and research and legal costs. The report also presents, and describes the methods used to estimate the distribution of costs among Brittany, France, and the rest of the world. The total economic costs to the world were estimated to range from about 800 to 1200 million 1978 francs (approximately 190 to 290 million 1978 U.S. dollars). The largest components of the total cost were cleanup expenditures, losses to the oyster-culturing industry, and the loss of the tanker and cargo. The loss to recreationists was estimated to range from about 6 million 1978 francs to about 350 million 1978 francs, depending on the unit values of losses assumed.

PREFACE

The National Oceanic and Atmospheric Administration (NOAA) is the civilian ocean agency of the United States government. Because of its broad marine resource management responsibilities, NOAA has long been concerned with the problem of establishing accurate economic values for goods and services provided by the oceans. Within this general subject area, one problem which had received comparatively little economic analysis was the valuation of damages to those resources and services in economic terms (social costs) as a result of spills of oil and hazardous materials. At the time of the Amoco Cadiz oil spill in March 1978, only a handful of carefully prepared studies on the costs of such incidents existed.

To help fill this void in our knowledge of such incidents, NOAA commissioned the damage assessment reported in this volume. The primary goal of the project was to test methodologies that could be used not only to estimate the social costs of the Amoco Cadiz accident, but could also be used in assessments of damages from future spills of oil and hazardous substances into marine waters. The need for a set of analytical methods has become even more critical since the inception of this study with the passage in the United States of the Comprehensive Environmental Rehabilitation, Compensation and Liability Act (CERCLA) of 1980. This statute requires the federal government to establish a damage assessment program to provide compensation for damages to natural resources held in public trust from spilled oil and hazardous substances. Such assessments are to use the best available procedures for large spills and a standardized set of simplified procedures, requiring minimum field work, for small spills.

During the summer of 1978, a series of meetings was held between French governmental officials and representatives of NOAA to consider the request by the latter for permission to undertake the study and to solicit the cooperation of the French government in helping investigators obtain necessary economic data. Agreement was reached in August 1978 wherein the French government agreed to help facilitate the study, but chose not to take an active role in its execution.

Having secured permission for the study, NOAA's immediate task was to assemble a team of experienced analysts to develop and implement a research design for the project. This work began in the fall of 1978 with financial support provided by the Office of the Administrator and the Office of Coastal Zone Management, NOAA.

The team of investigators was made up of experts in the fields of natural resource and environmental economics from Canada, France, and the United States. Logistical and administrative support services were provided by the University of Rhode Island's (URI) Center for Ocean Management Studies under contract to NOAA. Overall project management was the responsibility of the Office of Ocean Resources Coordination and Assessment (ORCA), one of three program offices of the Office of Coastal Zone Management. Individual members of its professional staff participated directly in the actual analytical work. A list of project staff follows.

Most of the data on the economy and demography of France and much of the information used to estimate the financial costs of the spill to that country were obtained directly from French governmental sources. Additional data used to measure the effects of the spill on the local economies in the immediate area of the accident were obtained through local government offices. Supplemental information on the effects of the spill on businesses and labor, e.g., hotel owners, fishermen, and oyster growers, was obtained through their professional organizations and from personal interviews. In addition, a questionnaire survey of tourists was conducted in the spill region during the summer of 1979 to try to determine the effects of the oil spill on their behavior.

This study benefited from a large body of scientific research carried out on the fate and effects of the spilled oil in the environment. Some of the most important data were obtained through a multiyear program of natural science research organized through a French-American bilateral scientific commission. NOAA's Office of Research and Development was actively involved in the bilateral natural science research program. However, the economic damage assessment, the subject of this report, was not connected with the work of the bilateral commission.

At the outset of the study there was a recognition within NOAA that, because of the uniqueness of the project and the anticipated difficulty of carrying it out, there was a need for careful and timely peer review. In the fall of 1979 NOAA appointed a six-member review panel to provide independent, critical commentary and professional advice to the agency and the team of investigators. NOAA appointed all six members. However, two were appointed in consultation with two of the chief litigants in the complex legal proceedings that have been under way since the accident, Standard Oil of Indiana (Amoco) and the Republic of France. The insights and critical remarks of all members of the review panel provided invaluable assistance to the investigators and to NOAA in completing the study.

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THE SOCIAL COSTS OF THE AMOCO CADIZ OIL SPILL: INTRODUCTION AND SUMMARY

INTRODUCTION

Shortly after dawn on the morning of 16 March 1978, the fully loaded supertanker Amoco Cadiz (223,680 deadweight tons) lost its steering at the southern entrance to the English channel. About 2100 local time on 16 March, the Amoco Cadiz drifted onto submerged rocks about 1.5 kilometers (0.9 mile) off the coast of Brittany near the small fishing village of Portsall, France (Figures 1–1 and 1–2).

At the time of its grounding the Amoco Cadiz was only a few hours running time from its immediate destination of Lyme Bay on the English coast. It would have off-loaded part of its cargo there before continuing on to its final destination of Rotterdam, the Netherlands. The vessel was following the normal route for tankers bound for North Sea ports.

Efforts to free the tanker failed. Because of the prevailing gale-force winds, stormy seas, and dangerous shoals in the area, transfer of the cargo proved impossible. Shortly after the grounding of the vessel, oil began to spill into the ocean. Oil continued to spill from the tanker until it was bombed on 29 March to release the remaining oil on board. All of the approximately 216 thousand tons (metric)[1] of the cargo of light Arabian crude and the approximately 4 thousand tons of bunker fuel remaining at the time of the grounding were spilled.

Important features of the Amoco Cadiz oil spill were the scale of the spill; the severe weather conditions at the time of, and subsequent to, the event; and the location of the spill in shallow water close to shore. The amount of oil spilled into the ocean from the Amoco Cadiz was about twice the amount spilled from the supertanker Torrey Canyon in 1967, about six times the amount spilled from the Argo Merchant in 1976, and roughly twenty times the amount of oil discharged during the Santa Barbara Channel oil well spill in 1969.

The severe weather conditions prevailing at the time of, and subsequent to, the grounding not only made it impossible to rescue the tanker itself by towing, but also precluded transferring the cargo to other vessels. In addition, the high waves and gale-force winds made ineffective the use of equipment to contain and recover the oil at sea. The winds blowing in the onshore direction, the proximity of the spill to shore, and the continuance of the severe weather conditions for several days following the accident, drove much of the oil onto the coast. Because of concern about the potential effects of dispersants on nearshore biota, dispersants were prohibited from use in waters less than 50 meters deep. Finally, the shallow water and rocks in the vicinity of the grounding made the maneuvering of other vessels involved in the spill response difficult and dangerous.

The amount of oil reaching the shore was estimated to have been 60–65 thousand tons, or about 30 percent of the total spilled (Gundlach and Hayes, 1978; Finkelstein and Gundlach, 1981). The remaining 70 percent was dispersed throughout the water column; dispersed in sediments; or modified through photooxidation, biodegradation, and evaporation. An estimated materials balance for the spilled oil is shown in Figure 1–3.

As the oil left the vessel it mixed with water to form an emulsion, commonly termed "mousse," containing 20 to 30 percent oil. Aided by prevailing winds and currents, about 245 thousand tons of mousse were eventually deposited along about 400 kilometers (about 240 miles) of the Brittany coastline. The heavily oiled area (spill zone) extended from Le Conquet to Ile de Brehat. The two departments[2] directly affected were Finistere and Cotes-du-Nord (Figure 1–2). The affected area covered all or parts of three fisheries administrative units, the quartiers maritimes of Brest, Morlaix, and Paimpol.

After the Cote d'Azur of southern France, the Brittany coast is the most popular summer vacation area in France. Marine-related tourism, oyster culturing, lobster harvesting and storage, and open-seas fisheries are second only to agriculture as the primary economic activities of Brittany. The oil spill caused considerable direct damage to fisheries located in the spill zone, and the negative, world-wide publicity which accompanied the accident and its aftermath affected public perceptions of the quality of the region's beaches and contributed to a decline in tourism during 1978. In the months following the oil spill, journalists and individuals associated with affected localities and industries made numerous assertions about the extent of lost earnings in the fishing and tourist industries, and the extent of cleanup and restoration costs, property damages, and other effects. The magnitudes of the short-run and long-run physical, biological, and monetary damages as a result of the spill became questions of national and international focus and interest.

THE STUDY OF THE SOCIAL COSTS OF THE AMOCO CADIZ OIL SPILL

Immediately following the Amoco Cadiz oil spill, various data collection and analysis activities were launched by marine scientists concerned with understanding the effects of the spill on living marine resources and their habitats. At the same time it was also recognized that assessing the economic consequences of the oil spill was essential, for at least three reasons.

First, it was important not only to produce estimates of the economic costs of this particular oil spill, but it was also important to apply and test existing, and to develop additional, analytical methods that could be used in assessing damages associated with future oil spills and analogous marine pollution incidents. The Amoco Cadiz event provided a significant opportunity to review principles and apply analytical methods for estimating economic costs, to identify problems related to the quantification of damages, to suggest ways in which future studies could improve estimation of damages, and to suggest how the same results could be achieved in a more efficient manner.

Second, in developing oil spill damage reduction programs, it is essential to have information on the cost and effectiveness of various physical measures for reducing damages from spilled oil. Examples of these measures include removing oil from beaches of various types, removing and replacing artificially grown shellfish, and recovering and cleaning marine birds.

Third, claims and counterclaims would be made by various interested parties for actual or perceived damages incurred for which compensation would be requested. The estimation of the physical and ecological effects would be a necessary, but not sufficient, basis for the debates on claims.

It was recognized at the outset that every marine pollution event is unique. Nevertheless, it was believed that knowledge relevant to United States conditions could be gained by rigorous analysis of the economic costs of the Amoco Cadiz oil spill off the French coast.

Objectives of the Study

The study had two major objectives. The first was to apply, and to assess the applicability of, existing analytical methods for estimating damages from marine pollution events, such as oil spills, using the Amoco Cadiz spill as a case study. This first objective had two corollaries. One was to identify specific problems in estimating various types of damages and to suggest possible methods for improving the estimates, including specific data to be collected on a regular basis. The other was to identify (a) measures for reducing damages from oil spills which could be applied after a spill occurred; (b) the associated capital and operation and maintenance costs of different levels of application of those measures; and (c) the results achieved by their application, i.e., their cost effectiveness. It was recognized that, to some extent, physical measures are site- and weather-specific. However, because some are generally applicable, developing information on their costs and associated results would be useful for analyses of subsequent marine pollution incidents.

The second objective was to estimate the total net economic costs of the Amoco Cadiz oil spill, and to estimate the distribution of those costs by geographic area, e.g., region directly affected, nation of which region is a part. It was clear immediately after the event that significant costs would be incurred. Officials of the national government expected major cleanup costs. Fishermen would be unable to use their boats for fishing. Owners of and workers in tourist facilities anticipated losses in revenues and wages. Local public officials anticipated losses of certain fees because of reductions in numbers of visitors. However, depending on the ultimate disposition of financial responsibility for the spill, the residents of Brittany would pay less or more of the costs. To the extent that the French national government considered the costs a responsibility to be borne by all the citizens of the nation and paid compensation to individuals and entities in Brittany who bore the original costs, then the costs would be borne primarily by France. Some costs would be borne outside of France, as a result of gifts and other resources made available from non-French sources, and because certain losses were basically non-French, such as the value of lost cargo and lost tanker. In any marine pollution event, the distribution of costs is an important political, as well as economic consideration. Therefore, the second objective was defined in terms of both total costs and the distribution of costs.

Defining Costs

The definition of "costs" used in the context of this study is critical. The estimation of economic costs is in terms of the social costs of the oil spill. These costs are defined as the present value in 1978 French francs (and U.S. dollars)[3] of the time streams of reductions in real income for France and for the world as a whole which resulted from the spill. They include both costs measured directly by market prices, and damages, such as those to wildlife and aesthetics, which are not directly quantifiable by market prices.

The concept of social costs is based on principles derived from economic theory. For example, the lost value of landings of fish is a social cost because it indicates a loss of output of goods available for consumption. Similarly, the resources used to clean up an oil spill represent a social cost, if the resources are diverted from alternative, productive activities. Again, the output of goods and services available for consumption is reduced. In economic terms these costs are "opportunity costs," representing resources which were diverted from productive activities because of the oil spill.

In general, direct observations of prices can be used to measure the social costs of labor, capital, and other inputs—such as materials—used in particular activities. If resources are fully employed and highly mobile among activities, their prices reflect their values in alternative uses, i.e., their opportunity costs. However,

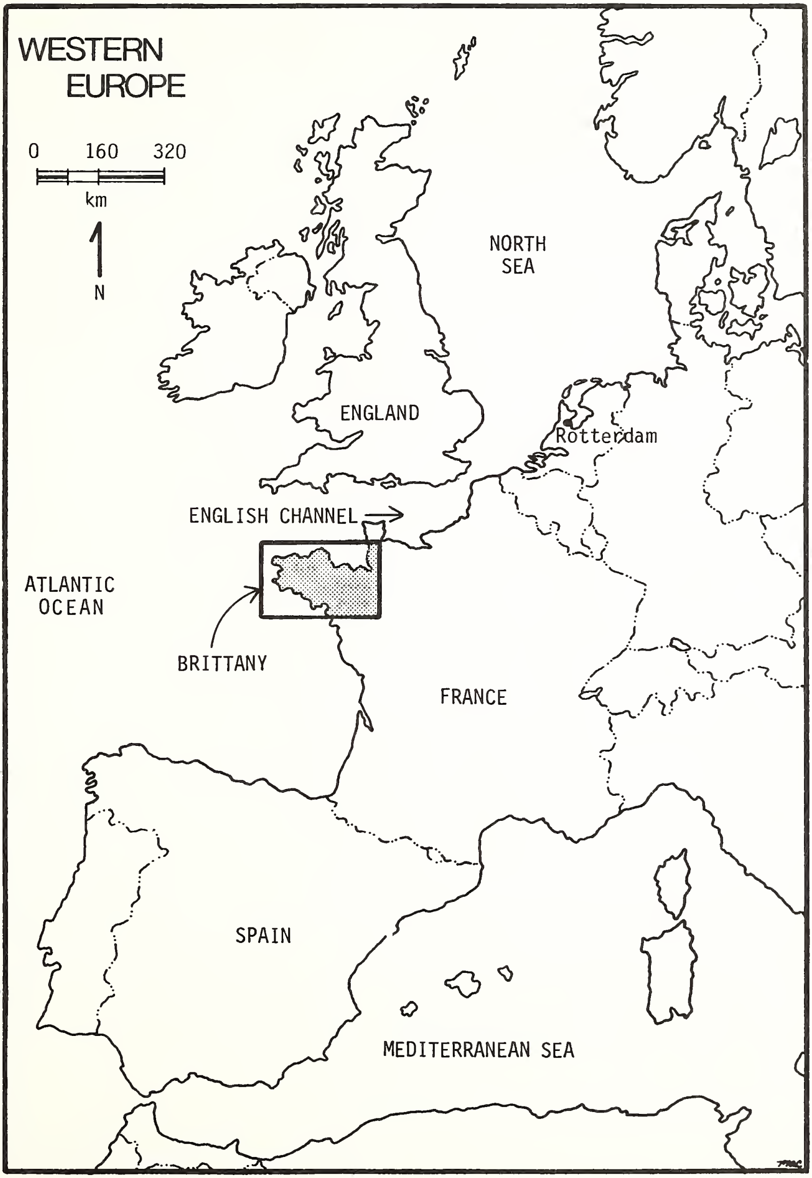

Figure 1-1.—Location of Brittany.

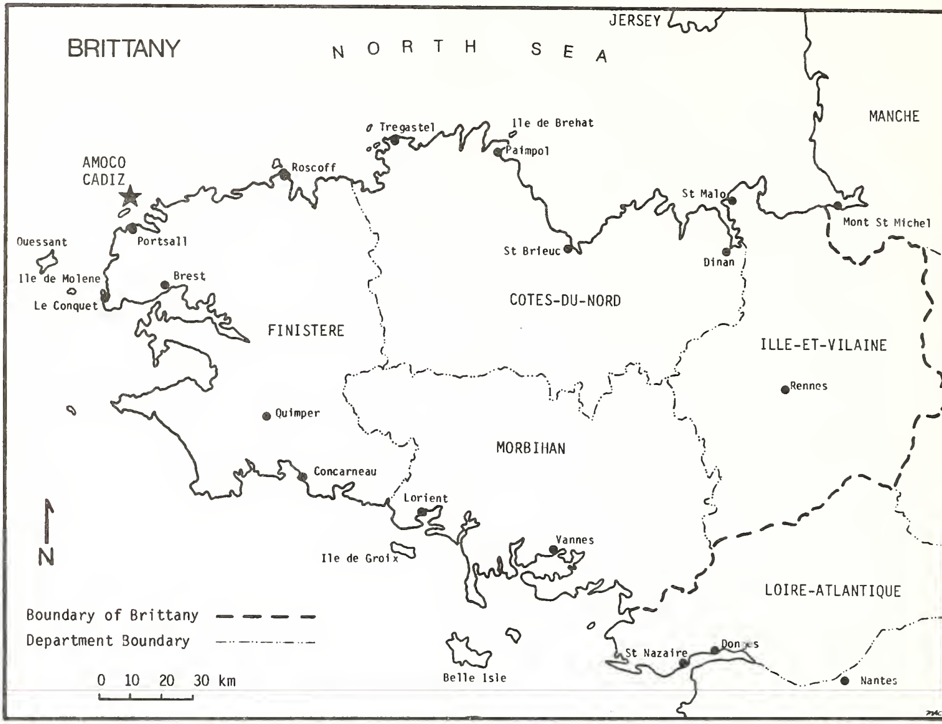

Figure 1-2.—Location of Amoco Cadiz Grounding and Oil Spill.

market prices may have to be adjusted to reflect true social cost under conditions of less than full employment of labor and capital. For example, the social cost of labor employed to clean up an oil spill would be less than its market cost, if the labor used otherwise would have been involuntarily unemployed. Such unemployed labor has few, or conceivably no, alternative productive opportunities, so that its use in cleanup operations would not involve a corresponding reduction in the output of goods and services desired by society.[4]

The fact that certain elements of the environment are not valued in the market place and are not subject to direct exchange between individuals or institutions does not mean that these elements have no value. They are as real as the purchases of bread and cars because individuals are willing to pay, for example, to preserve birds and scenic coastlines, using resources which could be used to purchase other goods and services directly. For example, this behavior is evident in the contributions individuals make to organizations which undertake efforts to clean oiled birds. There are, in principle, analytical methods—such as interview surveys—for obtaining estimates of the "willingness-to-pay" for such goods as avoiding damages to noncommercial wildlife. However, these methods are expensive, and their results remain controversial. With only limited funds available, efforts in this study to estimate non-market-valued costs were limited.

Two other points with respect to estimating costs should be made clear: (1) social costs compared with private costs compared with legally compensable damages; and (2) time streams of costs. *Social costs* must be distinguished both from *private costs* and from *legally compensable damages.* Social costs represent a net loss of real income, i.e., a net loss in real output of goods and services, for a defined population or geographic area. Some private costs are also social costs, as in the case of the destruction of privately owned stocks of oysters after contamination with crude oil, because these losses are not matched by any offsetting gains to society. But other private costs must be partly or wholly excluded from social costs, because they represent either transfer payments or secondary effects. Thus, in measuring social costs, transfer payments and secondary effects resulting from the oil spill are excluded, because they do not represent losses in real outputs of goods and services. Transfers are merely financial redistributions among members of society and do not con-

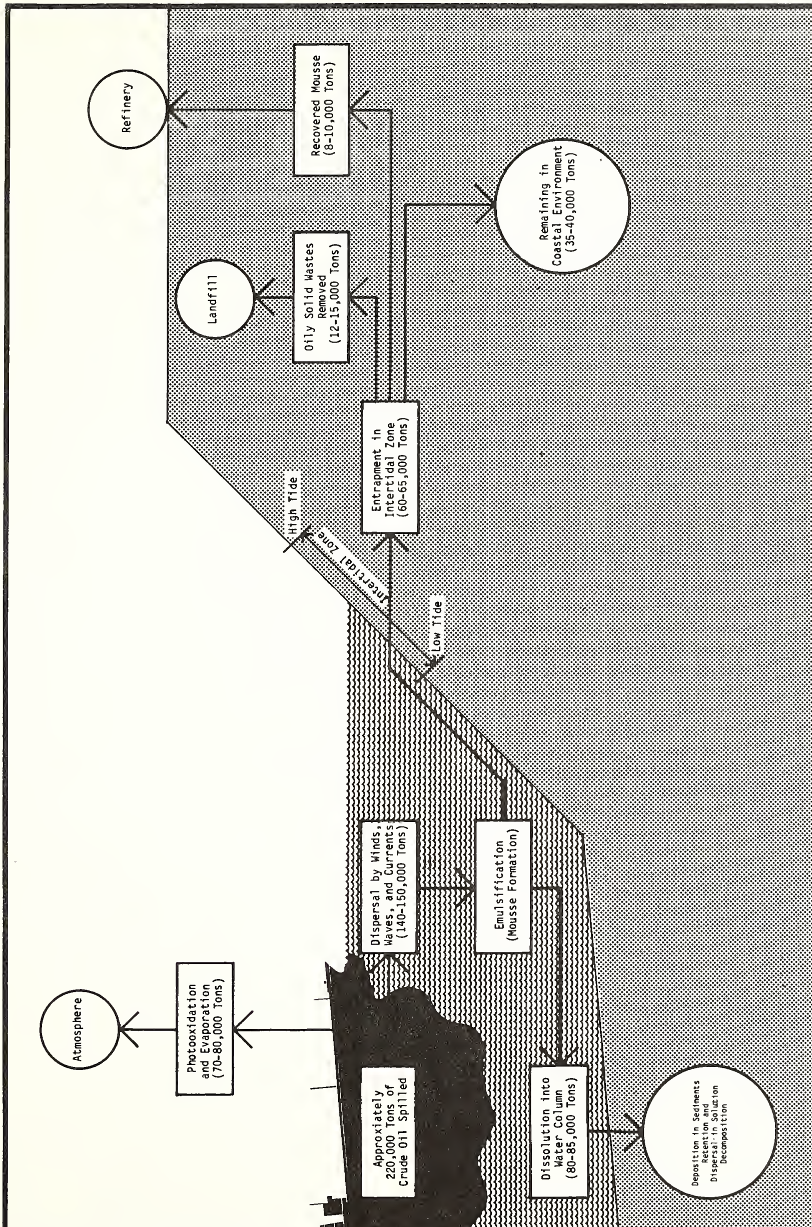

Figure 1-3—Estimated Materials Balance for Spilled Oil from the Amoco Cadiz.
(All weights are in metric tons of crude oil equivalents)

stitute a real cost to society as a whole. For example, a net loss in tax revenues from summer visitors will be a cost to the affected community, but it is merely a transfer to the nation, if that loss is offset by an increase in tourist-related tax revenues in other parts of the country. Another example of a transfer is the financial compensation paid to a region by the national government to reimburse the region for payments the region made to clean up an oil spill. Similarly, the unemployment compensation payments made by the French government to workers unemployed as a result of the spill should not be included. To do so would involve double counting, because the estimates of social costs already include the lost outputs which would have been produced by these workers made unemployed. Unemployment compensation payments do not represent any additional social costs to France, but rather represent a redistribution of existing real income. Thus, a transfer determines the distribution of costs but does *not* affect the total cost in terms of actual resources used.

Secondary effects refer to the indirect changes in regional income that result from a change in output of a regional industry. For example, a reduction in demand for tourist services in a region because of an oil spill will lead to a loss in earnings in the industry and to a reduced demand for supplies and services used as inputs by that industry. The reduced demands will cause indirect losses in regional income, if resources are thereby made idle or earn less. However, the secondary losses which occur in the spill area generally will be offset by secondary increases elsewhere, if tourist expenditures increase in other regions because of the spill. Thus, for the nation as a whole, secondary effects tend to cancel out and normally can be ignored in measuring social costs.

Legally compensable damages may have little in common with social costs, because the determination of their magnitude depends on the principles of common law, statutory law, or international agreements. Compensable damages may include social costs as well as transfers and secondary effects. For example, the U.S. Offshore Oil Spill Pollution Fund, established under Title III of the Outer Continental Shelf Lands Act Amendments of 1978 (P.L. 95–372), provides for compensation in the event of an oil spill from an outer continental shelf (OCS) facility or vessel. The Fund allows for compensation for cleanup costs (a social cost) and for local lost tax revenues (a transfer). The Fund also provides for compensation for secondary damages. For example, in a given region, a commercial or an industrial activity which incurred a loss in earnings because of an oil spill from an OCS facility or vessel could be compensated for its loss, even though the loss may be offset by gains in income in other regions because of the oil spill.

The second point meriting emphasis is that not all the costs associated with an event are likely to be incurred in the year in which the event occurred. This is particularly true with respect to effects on marine and coastal ecosystems. An oil spill may result in ecological damages such that affected living marine resources and their habitats may not recover for many years, if at all. In most circumstances knowledge is insufficient to establish, with reasonable confidence, a recovery period for most ecosystems and their component parts. Similarly, the tourist industry of a region may incur losses in years beyond the year of the spill, if tourists continue to avoid the area. In principle, damages should be measured over the entire time interval until conditions return to "normal." The estimate of costs through time can be stated as a lump sum by converting all future costs to an equivalent present value, using an accepted social rate of discount.

In summary, the social costs resulting from the oil spill are defined as the present value of the loss in real income. The estimate of total social costs can be considered the maximum amount that individuals would have been willing to pay in order to avoid the damages resulting from the spill. This amount would reflect alternative goods and services forgone.[5]

Social Costs to Whom?

Having stated that information on the distribution of costs is an important output of an analysis of the costs of a marine pollution event, having defined social costs, and having stated that what cost components are included depends on how geographic boundaries are drawn, the next step is to make these statements specific. The boundaries for estimating social costs must be specified, and the corresponding components of costs included within each boundary must be delineated.

In formulating this study, it was recognized that certain individuals and commercial and industrial activities in Brittany incurred financial losses which were "real" costs to those affected, but did not constitute social costs. Therefore, it was decided that the costs of the spill would be estimated from three perspectives: (1) net social costs to France; (2) net social costs to the world outside of France, i.e., "the rest of the world"; and (3) net costs to the residents of the Brittany region. The sum of the first two represents the *total net social costs* to the world resulting from the Amoco Cadiz oil spill.

For purposes of this study the net social costs to France =

[emergency response, cleanup, and environmental restoration costs]

\+ [value of lost outputs, e.g., reduced fish catch and oyster production, destroyed oysters, and reduced quality of outputs, e.g., tainted fish]

− [value of reduced fuel and other inputs *not* used because of reduced outputs][6]

\+ [losses of noncommercial marine biomass and losses of sea birds]

\+ [reduced profits and labor earnings to the tourist industry]

+ [losses to personal property, e.g., vessels, real estate]
+ [value of lost recreational amenities for French (non-Brittany) tourists and for Brittany residents]
+ [legal and research costs]
+ [damages to human health]
— [monetary contributions from outside France].

Only the third, fourth, and seventh components should require additional explanation. The third component of costs to France refers to expenditures which *would* have been incurred by various activities if 1978 had been a normal year, but were not incurred because the normal level of activity was reduced. This is exemplified by the reduced fuel use for some open-seas fisheries, a result of undertaking less fishing effort because of the oil spill. For the fourth component, part of marine resources, no credible methods for making monetary estimates of the estimated physical losses of noncommercial marine biomass and sea birds were available. However, it is important to indicate that they represent integral components of costs affected by the oil spill. The seventh component reflects the fact that residents of France who normally vacationed in Brittany either went to a less desirable (to them) location, or came to Brittany during the year of the spill but did not derive as much satisfaction from their visits as they would have without the occurrence of the spill. Residents of Brittany incurred similar losses in satisfaction.

The net social costs to the rest of the world =

[direct expenditures and gifts (from outside France) for emergency response, cleanup, and environmental restoration costs]
+ [value of lost vessel]
+ [value of lost cargo]
+ [value of lost recreational amenities for non-French individuals]
+ [legal and research costs]
+ [damages to human health]
— [increased profits and labor earnings in the tourist industry outside France, i.e., diverted from France because of the oil spill].

The net social costs to Brittany =

[emergency response, cleanup, and environmental restoration costs initially paid by individuals and entities in Brittany]
+ [value of lost, and reduced quality of, outputs, e.g., fisheries]
— [value of reduced fuel and other inputs *not* used because of reduced outputs]
+ [reduced profits and labor earnings to the tourist industry]
+ [reduced revenues to local government jurisdictions because of reductions in economic activities]
+ [secondary (economic) effects of reduced outputs in various industries and of reduced revenues to local jurisdictions]
+ [value of lost recreational amenities to residents of Brittany]
+ [damages to human health]
+ [losses to personal property, real estate]
— [compensation paid by the national government to individuals and entities in Brittany for costs and losses incurred, e.g., expenditures for cleanup, services provided, lost oyster production]
+ [that portion of compensation payments by the national government reflecting the share of national taxes collected from residents of Brittany].

The next section of this chapter describes the characteristics of the area affected by the oil spill and the nature of the time streams of resultant costs of the oil spill. Subsequent sections of this chapter and the rest of the chapters in this report describe how the different components of costs indicated above were estimated for each of the three geographical areas considered. The components are discussed in the following order: Chapter 2, emergency response, cleanup, and environmental restoration costs, collectively referred to as "cleanup" costs; Chapter 3, losses to marine resources; Chapter 4, losses in recreational activities of tourists and Brittany residents; Chapter 5, losses to the tourist industry; Chapter 6, other costs, including losses of the tanker and its cargo and research and legal expenditures; and Chapter 7, distribution of costs.

CHARACTERISTICS OF THE SPILL AREA AND DELINEATION OF THE ANALYTICAL PROBLEM

Characteristics of Brittany in the Area of the Spill

Figure 1–2 showed the location of the Amoco Cadiz oil spill just off the Brittany coast. Figure 1–4 shows in detail the portions of the coast affected by oil from the spill. The affected area is characterized by rocky headlands, crenulated bays, sandy beaches, and barrier islands. Short stretches of beach have been formed between erosional cliffs and long estuaries that mark the confluence of several rivers with the sea. The entire coastal area is geographically similar to the coasts of Maine and Southern Alaska and is highly productive biologically.

Brittany is a relatively remote and traditional region of France. The economy of northern Brittany is based primarily on agriculture, fisheries, and tourism. The fisheries sector is dominated by the production of aquacultured oysters. The open-sea fisheries are of marginal significance; only the harvesting of crabs and lobster is economically important. The economic value of the commercial catch of Brittany's fisheries amounts to only 4 percent of the total commercial catch of France.

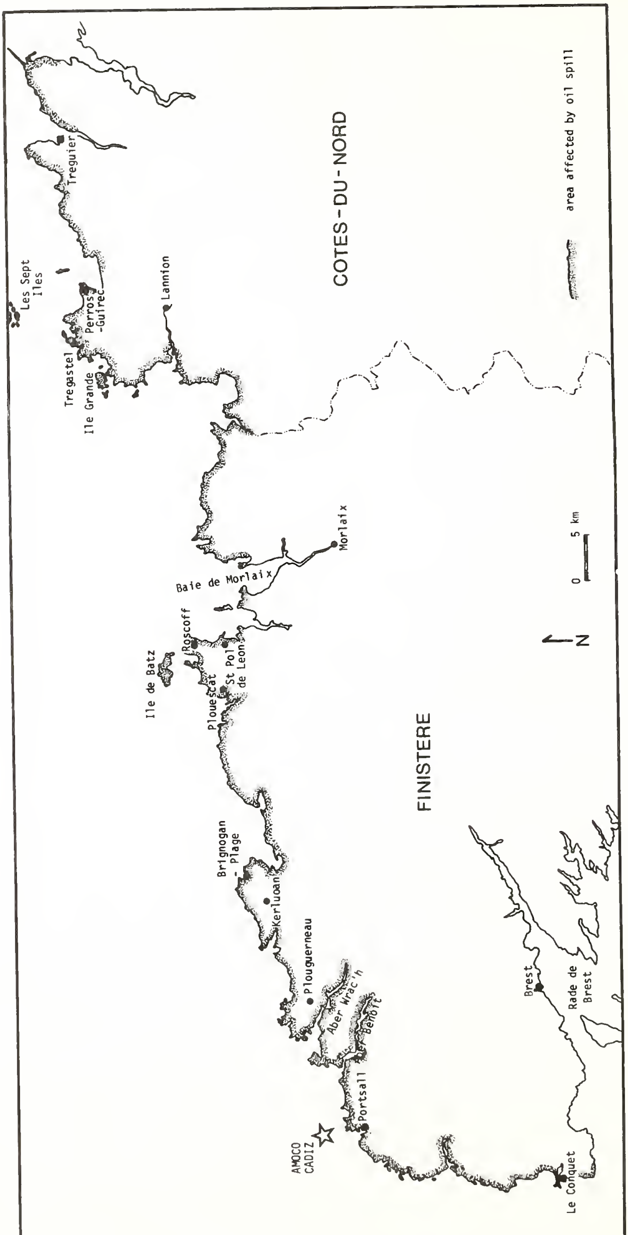

Figure 1-4.—The Brittany Coast Affected by the Amoco Cadiz Oil Spill.

Most of the commercial fisheries of Brittany are of the artisanal type in which most fishing effort is carried out by individual boat owners manning very small boats and fishing within sight of land. However, in recent years significant investments have been made in newer and larger fishing boats. Similar significant investments to modernize have occurred in the oyster-culturing industry, in activities relating to the holding of lobsters for marketing, and in the seaweed harvesting and processing industry. Nevertheless, the sum of all marine-related fishing activities is small in relation to the total income of Brittany.

The Brittany region is the second most important summer vacation area in France. The scenic shoreline and strong Breton family ties attract visitors from throughout France, especially western France and the Paris region, and from other European countries, particularly the Federal Republic of Germany, Belgium, and United Kingdom.

On the average, about 60 percent of the visitors to the Brittany shoreline come to Finistere and Cotes-du-Nord, the two departments physically affected by oil spilled from the Amoco Cadiz (Figure 1–2). Visitors to the region stay primarily in second homes, with relatives or friends, in rented rooms, or in camping facilities. Less than 10 percent of the visitors stay in hotels.

Tourism-related industries are concentrated in coastal communes. Many of the operations catering to tourists are small, owner-operated establishments with few or no salaried employees. The tourism-related industries account for about 15 percent of total employment in Brittany.

Delineation of the Analytical Problem

Figure 1–3 showed the estimated disposition of the oil spilled from the Amoco Cadiz. Sixty to 65 thousand tons of oil were estimated to have come ashore, primarily in the form of mousse. The normally high spring tides occurring at the time of the spill, combined with unusually large wind-driven waves, caused significant quantities of mousse to be deposited high up on beach faces, tidal flats, seawalls, and rocks, and deep into estuaries. The areas most heavily coated were westward-facing beaches, the seaward shores of barrier islands, estuaries, and marsh areas with western exposure.

In addition to surface coating, oil also mixed with sediment and penetrated the alluvial materials, resulting both in "(1) a more or less homogeneous low level oiling of the sand column, and (2) burial of discrete layers of oil within sediments, with high concentrations of oil in these layers" (Vandermeulen, et al., 1979, p. 223). A significant portion of the oil coming ashore was not removed during cleanup operations. Depending on climatic events, some of the oil may reappear. In addition, the toxicity of the stranded oil may have increased with weathering (Vandermeulen, et al., 1979, p. 227).

The effects on marine habitats of the oil combined with natural forces can be exacerbated by the methods of cleaning. Some areas, such as the Ile Grande marsh, were cleaned by removing the oiled grasses and substrate with heavy equipment. In this case the cleanup operation itself resulted in damage to the environment. Given the foregoing, the social costs of the spill should be delineated in terms of streams of damages and losses over time. With respect to some costs, such as cleanup, virtually all of the costs were incurred in 1978, the year of the spill. However, even with respect to cleanup costs, some costs associated with environmental restoration were incurred after 1978. With respect to tourism, the assumption was made—based on the available evidence and the judgement of knowledgeable French professionals—that the tourist industry in Brittany had returned to its normal level by 1979.

The time streams of damages to shellfish and finfish are more difficult to delineate. The immediate losses to the shellfish industry in 1978, e.g., those associated with destruction of some stock and removal of other stock, were readily apparent. Production was increasing toward pre-spill levels at the time of this study (1979). Estimates were then made of when the pre-spill levels would be reached. However, data available since the analysis indicate that the estimated time period until pre-spill levels of production are reached may have been optimistic. With respect to open-seas fisheries, catch typically varies significantly from year to year. Unless the marshes and estuaries—whose biological productivity was impaired beyond the year of the spill—were substantial sources of food for the open-seas fisheries, it would be expected that virtually all damage to these fisheries would be incurred in the year of the spill, assuming that the spill did not eliminate the reproductive class of any year.

Figure 1–5 depicts the estimated time streams of the major cost components. The solid lines represent quantities actually estimated in this study. The dashed extensions of those lines indicate costs which might have been, and might yet be, incurred. As far as can be determined, the costs not estimated represent a small portion, less than 5 percent, of the estimated social costs of the Amoco Cadiz oil spill.

CLEANUP COSTS

The news of the oil spill set in motion the French Plan Polmar, the interministerial plan initiated after the Torrey Canyon spill to organize French responses to oil spills and similar events. In the case of the Amoco Cadiz, a major effort involving as many as 35 ships, several thousand workers, and hundreds of pieces of equipment was made to try to contain and to clean up the spilled oil as expeditiously as possible. This response was organized in two components, Plan Polmar-Mer for the operations at sea, and Plan Polmar-Terre for operations on shore. Details of the organization of these two components are given in Chapter 2.

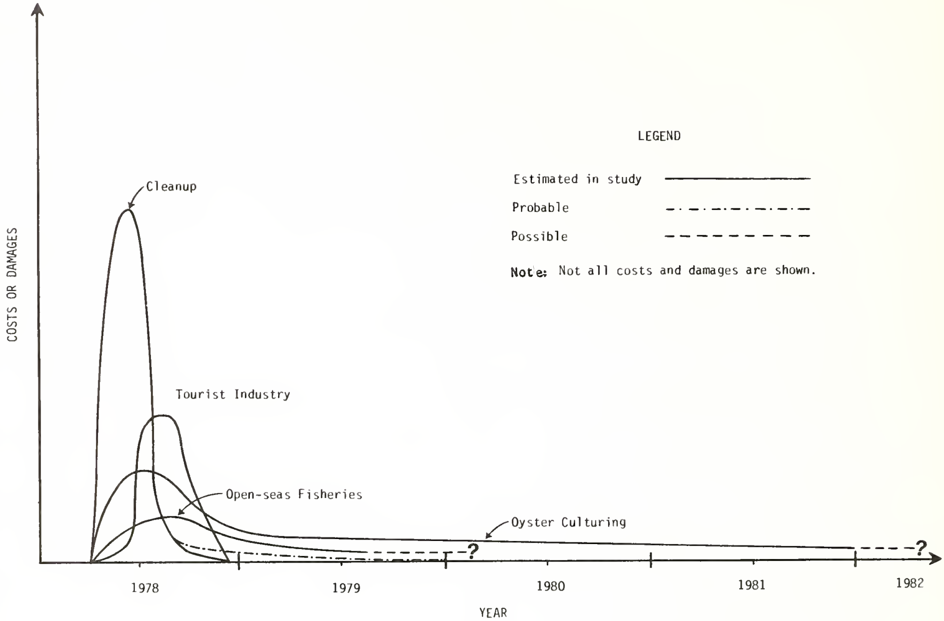

Figure 1-5.—Time Patterns of Costs and Damages, Amoco Cadiz Oil Spill.

Cleanup operations involved (1) removing oil, mousse, oiled grasses, and oily solid materials; (2) decanting oil to the extent possible; (3) transporting the materials to temporary storage; (4) transporting materials from temporary storage to final storage or processing; (5) restoration of facilities damaged by oil and/or by cleaning activities, e.g., sea walls; and (6) cleaning birds. Different types of equipment were used depending on the nature of, and accessibility to, the area to be cleaned. For example, areas such as the Wrac'h and Benoit estuaries posed special problems because access to the oiled shorelines was limited to the few existing entry roads. Heavy equipment, such as vacuum trucks, could be used only where there were firm foundations.

Data and Analytical Methods

Two basic types of data were available for use in estimating cleanup costs: (1) telex reports from headquarters directing the response effort; and (2) detailed records in regular government offices. With respect to the former, the pressing need of the oil spill response managers for adequate information on the availability of manpower and equipment and the relative productivity of various cleanup techniques necessitated the collection and publication of daily telex reports. These telexes were sent to spill response command headquarters directly from field operations in the spill zone and provided an excellent profile of the overall effort that was made. Each prefecture in the affected area, and most of the branches of the French central government that became involved, kept detailed records during the official period of cleanup operations on such items as the quantities of people and equipment which were used, the costs incurred, the quantities of material moved, and the amount of beach cleaned.

Cleanup costs included costs of materials and supplies; labor; rental of equipment including vessels, planes, helicopters, and pumps; equipment maintenance and repair; lodging, meals, transportation of labor; transportation of equipment; purchase of equipment; transportation and final disposition of collected oily materials. Quantities and amounts paid were obtained from invoices and bills for goods and services. Invoice verification and payment followed standard French accounting procedures. However, prices were checked to see that no excess profits had been made. Where prices were not given, market prices were applied or imputed to quantities indicated in the telex reports. Value-added taxes were subtracted, because—as noted previously—

they represent transfers and not actual social costs. Certain costs were obtained directly from records of governmental agencies, such as the French Navy with respect to costs of the vessels involved in the Plan Polmar-Mer operations. The standard unit costs developed by the French Navy were used. These include depreciation on, as well as operation and maintenance costs of, equipment. The major problems in estimating cleanup costs are discussed in the last part of this section.

Outputs were measured in terms of daily quantities of oil and oily solid materials collected and placed in interim storage, and daily quantities of liquid and solid materials transported from interim to final storage and processing. For some operations, costs could be associated with specific outputs so that productivity could be calculated.

Results

The net social costs of cleanup operations to France were estimated to be about 430 million to about 475 million 1978 francs. About 85 percent was attributed to the land-based component, Plan Polmar-Terre, and about 15 percent to the at-sea component, Plan Polmar-Mer. The estimated costs for both components are shown by expenditure category in Table 1–1.

In addition to the direct expenditures by France, expenses were also incurred by several foreign countries that assisted France during the cleanup operations. Available data indicated that the United Kingdom spent about 14 million 1978 francs and The Netherlands about 300 thousand 1978 francs. Some unknown additional amounts were spent by other countries, but the amounts were small. Thus, rest-of-the-world costs were esti-

Table 1–1—Estimated Cleanup Costs to France, Amoco Cadiz Oil Spill

Cost Item	Amount (1978 FR x 10^6)
At-Sea operations (Plan Polmar-Mer)	
Rented private vessels	15
Rented pumping equipment	6
Planes and helicopters, private and military	5
French Navy vessels	14
French Navy labor costs	9
Miscellaneous purchased equipment and supplies	1
Repairs and maintenance of Navy vessels	4
Chemicals	11
Transportation of Navy equipment and personnel	0.5
Total At-Sea Cleanup Costs	65
On-Shore operations (Plan Polmar-Terre)	
Army	97
Volunteer labor	8
Police	4
Miscellaneous expenditures by communes	2
Department of Equipment employees	9
Fire departments	4
Purchased equipment and supplies	87-130[a]
Rented equipment	86
Waste transportation and final disposal	42
Fuel	<0.5
Equipment repairs	10
Restoration and bird cleaning	14
Department of lighthouses and buoys	<0.5
Prefecture workers	<0.5
Interest charges	3
Total On-Shore Cleanup Costs	364-409
TOTAL COSTS	430-475 (103-114)[b]

[a] The range reflects the two alternative assumed residual values of purchased equipment, i.e., 50 percent and 25 percent, respectively.

[b] U.S. dollars (x 10^6) at exchange rate of 4.18 francs per dollar.

mated to be about 15 million francs, yielding total world costs of 445–490 million 1978 francs (about 106–117 million U.S. dollars).

Problems and Assumptions

Although the telex reports and agency invoices, bills, and records were excellent sources of data for the estimation of cleanup costs, various problems had to be faced, and some adjustments to the data and some assumptions had to be made. A listing of the problems and how they were resolved follows.

1. Identical data categories were not always used in the telex reports, agency invoices, and agency cost records. Care had to be taken to ensure correct interpretations of the data. Cost categories were based on the most highly aggregated scheme appearing in the telex reports.

2. Some suppliers of materials and services during critical situations, such as an oil spill, may attempt to raise prices above normal in order to earn extra profits. If that occurs, the expenditures for the materials and services so priced would overstate their true social opportunity costs. In the analysis it was found that the French government had established a schedule of prices it would pay at pre-spill amounts. A check of invoices and bills indicated consistency with that edict; hence, no excess profits were earned.

3. The labor services of soldiers, public works employees, firemen, policemen, and volunteers are not priced in ordinary market transactions. Therefore, the costs of these labor services had to be imputed. A correct measure of the costs of soldiers is likely to be given by the wage that would be necessary to staff the military entirely with volunteers. Unfortunately, this wage level is not known, because the Army in France consists of both volunteers and draftees. The wages received by career personnel and an imputed value for draftees, estimated as the average wage rate for unskilled labor in France, are indicative of what military personnel could have earned in alternative employment. The presumed labor opportunity cost, coupled with lodging, transportation, and other living expenses, was used to reflect military labor costs. With respect to public employees—including policemen and firemen—involved in the cleanup operation, their wages and bonuses, and the costs of their lodging, food, and supplies, can generally be assumed to approximate their social opportunity costs. With respect to establishing the value of labor of volunteers, employment conditions at the time are important. Volunteers were drawn largely from student populations, with the majority serving during Easter vacation. The minimum wage rate in France at the time was used as the best estimate of the social opportunity cost of the volunteers.

4. Capital goods that were purchased for use in the cleanup should be assigned a cost that reflects their residual values for subsequent use in other public works projects, including subsequent oil spills. Lacking any specific information on either type of future use, residual values of 50 percent and 25 percent of the original purchase price were assumed.[7] Thus, the cost of capital goods attributed to the Amoco Cadiz spill was 50 and 75 percent of the original purchase price. Similarly, supplies which were purchased for use in the cleanup, but were not used, should have their purchase prices modified to reflect residual values. Because no information on unused supplies was available, and because it appeared that the quantity of such supplies was small, no modification was made. This would result in a slight overestimate of cleanup costs.

5. At the time of the event, there was a stockpile of some equipment and supplies. These had been accumulated both in connection with previous oil spills and as part of contingency plans under Plan Polmar. Because no information was available on the types and amounts of such equipment and supplies, no estimate of their costs was included, although use was obviously made of them during the Amoco Cadiz cleanup operations. This would result in an underestimate of cleanup costs.

6. The costs reported by the French administration included value-added taxes, an item representing a transfer and not a cost to France. Accordingly, adjustments were made to reported costs to exclude value-added taxes.

Limitations

The limitations of the estimate of the social costs of cleanup should be made explicit. First, as mentioned above, costs of equipment and supplies existing at the time of the spill and residual values of supplies purchased during the cleanup effort, were excluded. The net result is a small underestimate of costs. Second, for some expenditures made in 1978 after the official period of Plan Polmar ended, there were no reports or records. This is particularly true for some expenditures by communes and by local residents. Third, some restoration activities continued into 1979, and probably beyond. However, no data on the costs of these activities were available, although the costs are believed to be small in comparison to those incurred in 1978. Fourth, the validity of the assumptions about the residual value of purchased equipment is not known. The assumptions could affect actual costs in either direction. Fifth, not all of the assumptions and accounting procedures were made explicit in the records of, or by, public agencies. The extent to which the assumptions and procedures are consistent with economic theory is not known.[8] The effect on costs could be in either direction. Sixth, it was not possible to estimate in monetary terms the value of all the cleanup assistance provided to France by other nations, although the total was very small in relation to total cleanup costs. This relates both to the direct services provided and to gifts made directly to individuals and entities in Brittany. To the extent that the gifts

represented *additional* expenditures for cleanup, i.e., not recorded anywhere, cleanup costs are underestimated by those amounts.

The composite effect of the foregoing limitations is believed to result in a small underestimate of cleanup costs, so that the estimated amount represents a lower bound. However, the analysts estimate that the underestimate is no greater than 5 percent of the estimated social costs of cleanup.

Implications

Several implications can be drawn from the analysis of cleanup costs. One, cleanup costs—in terms of achieving some specified level of cleanup—are strongly affected by weather conditions at the time of a spill, topography and geomorphology in the spill area, the resources available to apply to cleanup, and the *existing* institutional arrangement for organizing response to a spill.

Two, in general, the effectiveness of any particular type of cleanup method decreases over time. As natural forces disperse oily residues, output per unit of input falls steadily, implying successively higher costs over time for removing the same quantity of contaminated material. Thus, other things being held constant, declining productivity can be used as an argument for mobilizing resources quickly in response to a spill.

Three, the extent to which resources can be mobilized quickly in response to a spill depends on the prior existence of both an administrative structure for responding and some amount of equipment and materials being readily available. But providing organization, equipment, and materials continuously involves annual costs, i.e., spill damage reduction costs.[9]

Four, achieving reasonably complete and accurate estimates of costs depends primarily on having *in place* a system for keeping records on quantities of resources, e.g., workers and equipment, acquired and deployed in cleanup operations. Thus, for areas deemed to be subject to spills—just as for areas subject to floods, hurricanes, tornadoes, forest fires—basic systems for collecting and compiling data on inputs, costs, and outputs should be established.

MARINE RESOURCES

Social costs included under the category of marine resources were losses of existing stocks and of expected outputs in oyster culturing, other aquaculture operations, shellfisheries, and open-seas fisheries; damages to marine sand and gravel operations; damages to, and losses in value of, real property; damages to noncommercial marine biomass; and damages to marine-related birds. Virtually all of the estimated social costs to marine resources were incurred by the three categories of oyster culturing, shellfisheries, and open-seas fisheries.

Oyster Culturing

Only a small fraction of the oysters produced in Brittany come from natural oyster beds. Most are produced in artificial or enhanced environments, using modern methods of oyster breeding and culturing. Areas contiguous to bays and estuaries in France are part of the public domain; oyster producers lease these lands from the government on a long-term basis, usually 25 years. Significant investments are then made in the building of concrete impoundments (oyster parks) and other facilities, all of which become the property of the government when the leasing period ends.

Oyster culturing is complicated and painstaking. The first phase, termed "captage," usually occurs in the Bay of Morbihan in southern Brittany. Here collectors are placed in waters near the breeding sites, to which collectors the larvae eventually fix themselves. Later the baby oysters are moved to the Bay of Morlaix, where they are allowed to grow to an age of about 18 months. At this age, most oysters are moved to the Bay of Brest or elsewhere on the north coast of Brittany, where they are allowed to grow another year or more. Some may remain in the Bay of Morlaix throughout the life cycle. The oysters may be moved again, to be finished or "refined" in fresher waters, such as the estuaries Benoit and Wrac'h, where they obtain the desired color and flavor.

Two major species of oysters are grown in Brittany: the flat oyster, *Ostrea edulis,* the premier oyster of France; and the creuse oyster, *Crassostrea gigas,* a larger and more disease-resistant species. The latter was introduced in the region after a parasitic epidemic nearly destroyed the flat oyster culture of Brittany in the period after 1970. In 1977, the quartiers maritimes[10] of Brest and Morlaix together produced 16.5 percent of French production of creuse oysters and 10 percent of French production of flat oysters. The production of oysters in these two quartiers maritimes, where the impact of the oil spill was heaviest, involved 470 individual producers or firms, leasing 1,155 hectares of semi-submerged oyster beds and 522 hectares of deep-water beds. The oil spilled from the Amoco Cadiz did not reach all of these areas, especially the large areas of oyster beds in the Bay of Brest.

As soon as it was evident that the oil was approaching the oyster-culturing areas, the oyster producers initiated the transfer of oysters from areas being contaminated to non-contaminated areas. Not all of the oysters could be removed in time, so that some were lost immediately. Two other factors resulted in losses of oysters. One, oysters must be harvested and marketed at exactly the proper time. If they are allowed to mature too fully, the flesh will lose its tenderness and flavor and the oysters will have no value in the market. Oysters which were moved from the area affected by the spill could not be returned to the estuaries or to the Bay of Morlaix in time to permit proper development before marketing.

Two, and more significant, the oyster parks in the affected areas could not be sown with new stocks while the oil contamination continued. Thus, not only were losses incurred in the year of the spill, but also in subsequent years until pre-spill levels of production could be regained.

In addition to losses of existing stock and future production, oyster producers incurred the costs of cleaning equipment and buildings, and of replacing contaminated water with non-contaminated water. Further, although normal production was substantially decreased during the period of the spill and the cleanup period, the oyster producers maintained most of their work force because of the specialized skills involved. Thus, there was essentially no reduction in labor and maintenance costs.

Data, Analytical Methods, Related Assumptions, and Results

To estimate the social costs of the spill to the oyster-culturing industry of Brittany, five categories of costs were defined.

1. Value of the stocks of oysters destroyed at the time of the oil spill, amounting to about 1,240 metric tons in the estuaries and about 5,160 metric tons in the Bay of Morlaix. These stocks were valued at their wholesale prices at the time of destruction. The value of about 50 metric tons of mussels destroyed in the estuaries was included in this cost category;
2. Costs of transferring oysters from polluted to non-polluted areas such as the Bay of Brest, the Bay of St. Brieuc, and southern Brittany, and then returning them to the Bay of Morlaix or to the estuaries after the cleanup. These costs were calculated on the basis of distance in kilometers of transportation required for each transfer. In total, 200 metric tons of oysters were transferred from the estuaries; 1,300 tons were transferred from the Bay of Morlaix;
3. Costs of cleanup of personal property, equipment, and buildings of the oyster-culturing firms beyond that carried out by the government. This category of costs included *extraordinary* costs only, i.e., costs beyond those which would normally have been incurred in the production cycle;
4. Costs of cleanup and restoration of the lands leased by the oyster producers, in addition to the cleanup provided by the French government; and
5. Value of the loss of expected production of oysters over the years 1978–81, *net* of the loss of stocks accounted for in category #1 above.

Stock and production data, and physical loss data were obtained from individual oyster producers and from the Interprofessional Committee of Oyster Producers. Cost data were obtained from the same sources and from the French government. These cost data had to be adjusted (1) to eliminate costs included in the cleanup effort undertaken by the French government, and included in the cleanup costs described in the previous section; (2) to avoid double counting, e.g., counting the costs of unemployment compensation paid to workers in the oyster-culturing firms, these costs having been implicitly included in social costs in terms of their real output equivalent, i.e., the loss of oyster stocks and oyster production; and (3) to eliminate private (or transfer) costs, including payments by the oyster producers of the taxes due on their lease concessions and the interest due on loans for their oyster parks.

The estimate of future losses of oyster production was made on the basis of (1) pre-spill levels of annual production in the affected areas, i.e., 2 thousand tons in the estuaries and 9 thousand tons in the Bay of Morlaix; (2) the known recovery of the stocks through 1980; (3) the assumption—shared by many biologists in France—that the long-run recovery of the oysters is not seriously in question; and (4) the belief that the image of Brittany's oysters will not suffer any lasting damage which would impair their future value in the markets of Paris and elsewhere. On the basis of much discussion of these issues with owners of oyster-culturing firms, government specialists, and representatives of the Interprofessional Committee of Oyster Producers, it was concluded that oyster production would reach normal levels in the Bay of Morlaix in the 1981 season and in the estuaries in the 1982 season. Thus, the losses in production were based on the differences between *expected* levels of production and those actually achieved over the period required to reach pre-spill production levels.

Two assumptions were made in valuing the losses in production. One, the proportions of total production represented by flat oysters and creuse oysters would remain the same over time, at 10 percent and 90 percent, respectively. Two, the unit values used were the wholesale prices for these species in 1978, namely, 15 francs per kilogram for flat oysters and 4 francs per kilogram for creuse oysters. On the basis of these assumptions and the estimated losses in physical production, and using a real discount rate of three percent, the present (1978) value of lost production was estimated. The results of the analysis of social costs to the oyster-culturing industry are shown in Table 1–2. The industry was estimated to have incurred costs of about 107 million 1978 francs.

Limitations

The major limitation of the estimate of social costs to oyster culturing relates to the estimated time pattern of oyster production in the areas affected by the spill, particularly in the Wrac'h and Benoit estuaries. In 1981 the sediments in both were still contaminated with hydrocarbons, the effects of which on oyster production or value—because of lowered quality—are not clear. Thus, the assumption of no production losses beyond 1981 appears to have been too optimistic.

Table 1-2.—Estimated Social Costs to the Oyster-Culturing Industry.

Category[a]	Amount (1978 FR x 10^6)
1. Wholesale value of oyster and mussel stocks destroyed, or which were unmarketable after transfer	37.0
2. Costs of transferring oysters out of the polluted zone, and returning oysters after cleanup	1.2
3. Costs of cleanup and restoration of buildings, oyster parks, equipment of oyster producers, above the level of cleanup provided by the French government	5.3
4. Costs of cleanup and restoration of the lands leased by the oyster producers, above the level of cleanup provided by the French government	3.5
5. Value of loss of expected production of oysters over the years 1978-81, net of value of stocks accounted for in Category #1[b]	59.7
TOTAL COSTS	106.7

[a] Costs in first four categories were incurred only in 1978.

[b] The loss of expected production was valued without subtracting costs such as labor and equipment required for this production, because the oyster producers maintained most of their work force throughout the period of reduced output and continued expenditures required to maintain their stocks, equipment, and premises. Further, those employees who were temporarily laid off were unable to find alternative employment during their period of enforced idleness and thus produced no offsetting social income or product. The value of their leisure time might be considered an offset to the losses in oyster production, but the psychological costs of unemployment are assumed to have equaled or exceeded any benefits gained from leisure.

In addition, the loss estimate assumed that there would have been no increases in production over the pre-spill levels in the 1979–81 period in the absence of the spill. The validity of this assumption is not known. In both respects the assumptions made would yield a small underestimate of costs.

Holding Tank Operations for Shellfish (Viviers)

Enterprises involving holding tank operations for shellfish buy shellfish—mainly lobsters—from fishermen and then hold them in tanks for live delivery throughout the year to restaurant and retail buyers. Buyers are located in all parts of the world. Because a single lobster may sell for 50 francs, potential damage to this industry from the oil spill was large. Losses to the viviers stemming from the spill included contamination of tanks, seawalls, and grounds, in some cases requiring rebuilding of tanks; costs of transporting stocks to other areas; mortality to stocks too fragile to be transferred out of the oil spill zone; costs of replacing contaminated water in holding tanks with clean water brought in from outside the area; loss of expected income because of reduced levels of sales in 1978 and 1979; and costs of increased advertising and promotional activities which were made necessary by the change in the world-market image of the shellfish of Brittany.

Data and Results

The estimate of the social costs of the oil spill to the viviers was based upon data supplied by the affected firms. It was recognized that some of these data might not have been completely objective. However, adjustments were made only to eliminate double counting and to exclude private (transfer) costs which are not true social costs. Costs of overtime wages paid to employees who participated in the cleanup of premises or the transfer of shellfish stocks were included in social costs on the assumption that the rate of overtime wages is market-determined and represents the disutility associated with reduction in leisure time below the level allowed for in the normal work week. Extraordinary costs of advertising and promotion may not be social costs from the point of view of the world, because these activities may involve

rivalry with other nations who could occupy the market niche formerly filled by the French firms. From a national perspective, however, "product image" or "goodwill" is an intangible capital asset which produces real income for France. Erosion of this asset resulting from the oil spill represented a loss of real income to France; hence, an appropriate attempt to restore the value of this asset must be considered a legitimate social cost. The total social costs to the industry were estimated to be about 11 million 1978 francs.

Open-Seas Fisheries

The open-seas fisheries of Brittany include a number of species. These can usefully be combined into three groups reflecting biological and catch method similarities: (1) finfish, mainly pollock, mackerel, bass, plaice, and mullet; (2) crustaceans, i.e., lobsters, crabs, and shrimp; (3) and mollusks, i.e., clams, mussels, periwinkles, and cockles, but specifically excluding aquacultured oysters and scallops.[11] Estimating losses to these groups because of the spill involved attempting to estimate the difference between what the landings of fish and their value *would* have been without the spill, and what they were as a result of the spill.

Data, Analytical Method, and Results

The independence of the Brittany fishermen, and of the committees which represent their interests, has meant that statistics relating to fish catch and fishing effort in the region affected by the Amoco Cadiz oil spill have only recently been collected. With respect to fish catch, the data which were available included records of fish catch, both weight and *ex-vessel* value, by month and by port for about 150 species of fish and shellfish for the period January 1971 through December 1979. The data relating to fishing effort were more limited and came from different sources. Annual reports are published by the agencies of the quartiers maritimes. These reports give the number of licensed fishermen and the number, weight, length, and horsepower of licensed fishing boats within each quartier maritime. No catch data are reported for individual boats. Fishing effort—as opposed to the capacity of the fishing fleet—can be measured only by the quantity of fuel used by each boat in each quarterly period between April 1974 and December 1979, i.e., 23 quarters. Data on fuel use were obtained from records of fuel tax refunds made to individual boat owners. Because these fuel tax refund records are coded to the registration number of the boats involved, and registration records show the size, type, and horesepower of the boats, it was possible to construct a time series showing the total fuel consumption in each quarter for each *type* of boat within each port, and also the total average horsepower of the boats.

Because no catch data were reported for individual boats, it was not possible to estimate losses to open-seas fisheries by using a production function approach, that is, by developing a relationship between variables reflecting fishing effort, such as amount of fuel and vessel characteristics, and fish catch and related value. Therefore, a modified, trend-extrapolation, forecasting model was developed and applied. This model attempted to reproduce the real value of fish catch, in each month prior to the oil spill, and then predict what the real value would have been under "normal" conditions in the month of the spill and in each month thereafter through December of 1979.[12] The difference between expected catch (predicted by the model) and recorded catch is the estimated loss, or gain, for each month.

Regression equations were developed for the *three* classes of fisheries, i.e., finfish, crustaceans, and mollusks, for *each* of the quartiers maritimes affected by the oil spill, i.e., Brest, Morlaix, and Paimpol. The regression equations used were of the following form:

$$C_{iq} = a + bY + \sum_{j=1}^{11} c_j M_j + u_t, \qquad (1\text{-}1)$$

where

C_{iq} = real value of catch of the i^{th} species grouping in quartier maritime q by month;
a = intercept;
b, c_j = coefficients to be estimated;
Y = an annual trend variable;
M_j = monthly seasonal adjustment dummy variables; and
u_t = a randomly distributed error term.

The statistical coefficients for the independent variables for each equation were first estimated using the time series of the real value of catch for the period prior to the oil spill, i.e., from January 1971 through February 1978. The estimated coefficients for each equation were then used to forecast the *expected* real value of catch for each month following the oil spill, i.e., March 1978 to December 1979.

The cumulative losses or gains for the three quartiers maritimes and the three species groups for the period March 1978–December 1979 were derived by discounting the gains and losses for the months subsequent to March 1978, using a real discount rate of 3 percent. Then two adjustments had to be made to the totals of these values. First, some unknown proportion of the fish catch in Brittany is not officially reported. Part of this unreported catch is made by nonprofessionals, so-called "foot fishermen," who are allowed to fish for their own consumption without any license. According to French fisheries experts, these fishermen account for perhaps 5 percent of the total catch in each quartier maritime. Another part of the unreported catch is diverted to beaches or coves, outside of the ports where landings are officially reported, before the fishing boats return to port. There is a wide range in the estimates of the

proportion of unreported landings made by various investigators. In the absence of resources for a definitive study of the problem, the available data were reviewed and the assumption was made that, on average for all species and all areas, the fraction of the fisheries catch in Brittany which goes unreported was about 20 percent. Therefore, the loss estimates for each quartier maritime were increased by 20 percent.

Second, a small correction was made to account for the fact that a significant decline in fuel used by fishing boats occurred in 1978 in the quartier maritime of Paimpol. On the basis of the historical data, it was assumed that fuel used in 1978 would normally have reached the plateau level of about 400 thousand liters which was recorded in 1977 and 1979. The amount of fuel actually used in 1978 was about 100 thousand liters less than would have been expected under normal conditions. The savings in social costs, net of government taxes, associated with this reduction in fuel use amounted to about 42 thousand francs, based upon a social cost of diesel fuel of about 75 francs per barrel in France in 1978.

The final estimate of the net social cost to the open-seas fisheries of Brittany, totaling about 20 million 1978 francs, is shown in Table 1–3.

Table 1–3.—Estimated Net Social Cost to the Open-Seas Fisheries of Brittany.

Quartier	Finfish	Crustaceans	Mollusks	Total Loss
Brest	0.58	7.61	9.15	17.34
Morlaix	No loss	No loss	0.44	0.44
Paimpol	1.13	0.40	0.54	2.07
Less adjustment for reduced cost of fishing effort in Paimpol				-0.04
TOTAL NET COSTS (1978 FR x 10^6)				19.81

Problems and Limitations

The accuracy of the estimate of losses in real value of fish catch is affected by several problems. One is the accuracy of the estimates of fish landings. In Brittany, fish catches are estimated by a French government official who works in each port and who, through a combination of knowledge of species caught and of the capability of the fishermen operating out of the port, judges the size of each day's catch. In contrast, for many of the U.S. commercial fisheries, the catch by each boat is weighed on board and is recorded on a machine-readable "fish ticket." However, tests conducted in the United States have shown that the method used in Brittany does give reasonably accurate results. A related problem is that the prices paid to the Brittany fishermen are not always true "auction" prices, but it is difficult to know how adjustments might be made for the absence of a fully functioning competitive market. Hence, the official data on values of catch were accepted and used in the analysis.

A second problem, closely related to the first, involves the availability of data at the level of detail of individual boats. It is always difficult to obtain detailed data from fishermen concerning their vessel operations, but gathering this information in Brittany was especially difficult because of the artisanal nature of the open-seas fisheries and the system of record keeping which required considerable effort on the part of the investigators to put the available data into a form suitable for analysis. Granting that it will never be possible to obtain data easily, the prospects of obtaining more detailed catch and effort information will be better for countries and fisheries where boats are larger and where a greater proportion of the catch is sold through organized markets than is done in the open-seas fisheries of Brittany.

A third problem involves the assumption made about how long it took for the effects of the oil spill on fish catch to disappear. Inspection of the results for each of the species groups for each of the quartiers maritimes shows that the net losses incurred in these fisheries are very much a function of the number of months which are included in the loss period. A reasonable scientific rule for selecting the loss period would be based upon some definitive biological study of fish stocks, with the loss period ending when the stocks had returned to normal. Because there do not appear to be any such studies of fish stocks for the region, the loss period had to be assigned on a more arbitrary basis. A loss period for each species group which maximizes the net loss recorded for that group is clearly inappropriate because, during a recovery period, some of the early losses of catch will very likely be recouped. Given the data which were available, covering 21 months following the oil spill, selecting the true period of loss for some species groups would obviously not have been possible if the losses for the groups extended beyond December 1979. Both natural environmental perturbations and varying economic conditions affecting fishing make the operational determination of a loss (or recovery) period difficult. Thus, there was a necessary element of arbitrariness in the choice of a loss period. The decision was made to report fisheries losses for the period extending to the end of the data series, i.e., through December 1979.

A fourth problem, an unknown but appraised to be a minor limitation of the analysis, is that no attempt was made to model the demand side of the fisheries markets. Brittany's fisheries represent about 4 percent of the value of French fisheries, and the price effects of supply disruption in connection with the oil spill were small and temporary. The movement of fisheries products within the Common Market, and from one region

of France to another is routine. Thus, a rapid adjustment to the loss of outputs from one small fishery, i.e., that of north Brittany, could quite easily—and apparently did—occur. Demand studies of Brittany fisheries would have been a major undertaking. In view of the relatively minor role of Brittany fisheries in France as a whole, such an effort was not warranted.

Damage to Fishing Boats and Equipment

A final category of social costs to the open-seas fisheries of Brittany comprised damages to the fishing boats, motors, and gear, which were not included in the French government's cleanup effort and, thus, not reported as part of the costs of cleanup. To obtain an estimate of these costs, a mail survey of fishermen was undertaken in the summer and fall of 1980. The survey was believed to have provided a reasonably accurate picture of the effects of the oil spill on fishermen.

In the population sampled, the average fisherman operating a boat out of one of the ports affected by the oil spill was estimated to have incurred an extraordinary cost of cleanup and repair of his equipment amounting to about 3 thousand francs. These costs were probably not uniform among all ports and all quartiers maritimes, but the differences should not be very great, because the Amoco Cadiz oil found its way into all 13 ports for which damages in this category were estimated. Assigning an average out-of-pocket cost of 3 thousand francs for cleanup and repair to each of the 371 fishing boats which operated out of the 13 affected ports in 1978 yielded an estimate of about 1.1 million 1978 francs in damages to fishing boats and equipment.

Other Marine-Related Social Costs

Investigations of the seaweed harvesting and processing industry, salmon/sea trout/abalone experimental aquaculture operations, and marine sand and gravel operations revealed minimal damage in each case. Damage to sea walls, buildings, equipment, and boats associated primarily with the health-related hotels and clinics in Roscoff was estimated to be only about 1 million 1978 francs. Real estate agents interviewed in the most affected area unanimously concluded that the spill had had no effect on property values. Even if there had been an effect it would have been slight, and it would have been impossible to have disentangled the effect of the spill from the effect of general economic conditions in France at the time.

That substantial numbers of various species of noncommercial marine biomass were destroyed by the spill is not in question. Surveys along the affected coast produced evidence of mortality of individual organisms in the hundred millions. However, having such information is of no use unless a credible unit value can be associated with a loss of each species. Conceptually this could be done, if the role of any given species of noncommercial marine biomass in the food chain in relation to a commercial species were known. However, such information was lacking, and, because there was no other credible method to assign a unit value, in this chapter the impacts on marine biomass were simply described in physical terms, and no monetary estimate of damage was made.

Similarly, a detailed review was made of the estimates of the numbers of different types of birds whose deaths were attributed to the oil spill. Not only the immediate loss was considered but also the long-run effects, such as might occur if the breeding population of a particular species had been decimated. It did not appear that effects of that degree of criticality occurred. Because no credible method exists for placing a unit value on each species of affected bird, no monetary estimate of damages to marine-related birds was made.

Summary of Costs to Marine Resources

The estimated social costs to marine resources are summarized in Table 1–4, in terms of 1978 present values. About three-fourths of the costs were incurred by the oyster-culturing industry; about 85 percent were accounted for by the total of oyster-culturing operations and viviers of shellfish, reflecting the importance of these fisheries and their special vulnerability to the oil spill. Open-seas fisheries accounted for about 14 percent of the marine resources costs of the spill.

RECREATION: TOURISTS AND RESIDENTS

Markets and prices are vitally important for determining values of goods and services in monetary terms. However, the prices and values of some goods and services are elusive, largely because organized markets for their exchange do not exist or are not readily observable. When prospective tourists to Brittany went elsewhere in 1978 because of the Amoco Cadiz oil spill, or tourists who actually came changed their activities, their expected welfare must necessarily have decreased or they would have chosen the alternative of going elsewhere, or engaging in other activities, in the first place. Similarly, residents of Brittany suffered some welfare losses associated with changing their recreational activities as a result of the oil spill. These welfare losses represented non-market-valued social costs of the spill associated with recreation.

Three categories of social costs to recreationists were identified and estimated. First, an estimate was made of the non-market-valued costs incurred in 1978 by tourists who had planned to come to Brittany but went elsewhere because of the oil spill. Second, estimates were made of the non-market-valued costs incurred by tourists who came to Brittany but changed their activity patterns and the beaches they visited as a result of the oil spill. The changes in activity patterns resulted in

Table 1-4.—Summary of Estimated Costs to Marine Resources.

Category	Present Value of Cost, (1978 FR x 10^6)
Oyster-culturing industry	107
Seaweed harvesting and processing industry	<0.1
Holding tank operations for shellfish	11
Salmon, sea trout, abalone experimental aquaculture operations	<0.1
Open-sea fisheries	20
Uncompensated damage to fishing boats and equipment	1
Marine sand and gravel operations	0.1
Damage to real and personal property	1
Changes in value of real property	Negligible
Noncommercial marine biomass	[a]
Marine-related birds	[a]
TOTAL COSTS	140 (33)[b]

[a] No estimate of monetary cost possible.

[b] U.S. dollars (x 10^6) at an exchange rate of 4.18 francs per dollar.

some loss in satisfaction. With respect to these two categories tourists were defined as those who remained at least five days in Brittany, and who stayed in hotels, in campgrounds, in second homes which they owned, in rented rooms or houses, or with relatives or friends. The third category involved residents of Brittany who changed their recreational patterns as a result of the oil spill, thereby incurring some losses.

Data, Analytical Methods, and Results

Estimating the social costs associated with these three categories depended on estimating the numbers of individuals in each of the categories. The first step in doing so involved estimating the reduction in the number of tourists going to Brittany in 1978 because of the oil spill.

It was clear that there was a reduction in the number of tourists who went to Brittany in 1978, in comparison to the numbers who would have been expected in the absence of the spill. But it was also clear that the colder than normal weather in the first part of the vacation season contributed to the decrease in the number of tourists.

The estimate of the reduction in tourists to the Brittany coast in 1978 was derived by first assuming that the number of tourists who *did* come to Brittany in 1979 represented the number who would have come in 1978 if the spill had not occurred. A survey by the Institut National de la Statistique et des Etudes Economiques (INSEE) of visitor accommodations (other than hotels) in the summer of 1979, yielded an estimate of 1.74 million visitors in July and August of that year. From various sources the following estimates were obtained of the decreases in occupancy rates in 1978 compared to normal: for hotels, 10 percent; for camping areas, 15 percent; and for other types of accommodations, 7.5 percent. The "other" category comprised second homes, rented rooms in homes, and free rooms with friends or relatives.

Applying these rates to the total of summer visitors in 1979 yielded an estimated *decrease* of about 185 thousand summer visitors in 1978 because of the oil spill. On the basis of previous surveys that showed about three-fourths of the total visits to the coastal area in a year to be in the two summer months, an estimate of a reduction of about 245 thousand visitors for all of 1978 was made. These were the individuals who did *not* come but went elsewhere. Subtracting this number from the estimated total number of visitors, 2.32 million,[13] yielded the estimated number of vistors who *did* come to the Brittany coast in 1978, 2.07 million; these constituted

the second category. The individuals in the third category were the residents of the coastal area[14] of Finistere and Cotes-du-Nord, about 237 thousand.

Estimating Unit Losses and Total Losses

The number in each of the three categories having been estimated, the next step was to estimate the unit loss associated with each visitor in each category. Then these estimated unit losses were applied to the respective number in each category.

Those Who Did Not Come. Because it was impossible to interview individual families of tourists, both from within and without France, who did not come to Brittany in 1978, 17 tour operators in the Federal Republic of Germany[15] were used as proxies for those who did not come, because the largest group of foreign tourists to Brittany comes from Germany. These tour operators provided various types of package tours to a wide-ranging clientele. Many of the tours involved contracts, so that if the individual or family canceled the trip to Brittany, the loss to the tourist ranged from his deposit up to 100 percent of the price of the tour.

The 17 German tour operators, each representing his agency, were interviewed in German in Germany, and were asked whether or not tourists who had canceled would have been willing to have paid more money in order to have had the same quality of vacation experience as had been expected of the visit to Brittany. Three responses were obtained: (1) tourists would not pay more; (2) tourists would pay an additional amount of between 3 and 10 percent of the cost of their tour package; and (3) tourists would pay an additional amount of between 10 and 20 percent. The magnitude reported seemed to be independent of the cost of the tour or the size of the agency. A reasonable single figure to use as the cost to tourists who did not come because of the spill was considered to be about 5 percent of the cost of their tour packages. The total cost of the packages varied in 1979 from about 770 francs to about 4,600 francs for two weeks. For an average visit of 2 to 2 1/2 weeks the average cost was estimated to have been about 3,800 francs. Combining the 5 percent figure selected as a measure of a tourist's willingness-to-pay with the average tour cost of 3,800 francs yields about 190 francs as the unit loss in welfare, i.e., the social cost of one tourist's forgone visit. Applying this unit value to the 245 thousand tourists estimated not to have come in 1978, yields an estimated loss of about 46.6 million 1978 francs.

Those Who Did Come. Estimating the monetary losses incurred by those who came to Brittany in 1978, but whose satisfaction was reduced by the oil spill, was even more difficult than valuing the losses incurred by those who did not come. These losses are related to the willingness of individuals to pay for recreational experiences. Two analytical methods were used to obtain monetary estimates of losses to tourists who came, in terms of willingness-to-pay. The first was the travel cost method. The second involved asking respondents hypothetical questions to elicit their willingness-to-pay for, or be compensated for, changes in the quality of their recreational environments.

For a given recreation site the travel cost method uses differences in participation rates resulting from differences in travel costs to visit that site to estimate the willingness-to-pay to visit the site. Although the travel cost method is usually applied to a specific site, in this case the Brittany coast as a whole was treated as if it were one specific site. It was also assumed that each trip to the region was a single-destination trip to a single central point on the Brittany coast, the town of Brignogan-Plage.

Geographic origins of French tourists were grouped into zones within which travel costs to the Brittany coast could be assumed to be relatively equal. Then the visit rate per unit of zone population was calculated for each zone. Assuming that tourists across zones were relatively homogeneous, and that tourists within a given zone were not different from other individuals in that zone, the functional relationship between travel cost associated with the zone and the visit rate for the zone gave the *form* of the demand curve of the representative individual in that zone for visiting the Brittany coast. Once zone-specific demand curves were obtained, aggregation across tourists within and across zones was possible, to yield the aggregate willingness-to-pay to visit the region.

The objective in using the travel-cost method was to compare demand curves for visiting the Brittany coast for the years 1978 and 1979, to see whether or not they were significantly different. The hypothesis was that, during 1978 when the oil spill occurred, demand would be reduced and hence would be less than in a "normal year" such as 1979.

Basic data for application of the travel-cost method were obtained in two surveys, one each in 1978 and 1979, conducted by the French Institut National de la Statistique et des Etudes Economiques. For 1978 and 1979, the samples comprised, respectively, 1,199 and 4,024 usable observations. The samples represent about 1 in every 1,726 tourists in 1978 and 1 in every 577 tourists in 1979, on the basis of the previously described estimates of recreational activity in Brittany. For reasons which could not be determined, the samples included no foreign tourists, although several hundred would have been expected in purely random samples of 1,000 to 4,000 tourists.

Using the above data, the travel-cost method yielded an estimated loss to each visitor of about 3 francs. Applying this unit loss to the estimated 2.07 million visitors who did come yields an estimated loss of about 6.2 million 1978 francs.

The foregoing analysis was based on actual behavior of visitors; i.e., those interviewed had actually traveled specific distances to reach the Brittany coast in 1978 and 1979. In contrast, in a separate sampling of both

tourists and residents in the summer of 1979, interviewers asked a series of questions depicting hypothetical situations. The number interviewed was limited by available funds; the size and categories of the sample are shown in Table 1–5. The interviews were conducted by the French market research firm, Organization des Developpements Economiques et Sociales (ODES).

The first set of questions involved probing how far households would travel to a clean beach and how often. Pictures of heavily oiled beaches, to represent nonclean beaches, were shown interviewees. On the basis of the answers, and a travel cost of one franc per kilometer, a "willingness to incur increased travel costs to avoid pollution" function for households was estimated. This function was assumed to be equivalent to a willingness-to-pay function for clean beaches. Using this function yielded a mean seasonal willingness-to-pay of about 490 francs, which represented the mean willingness-to-pay of a family for a clean beach. Using the mean family size of 3.8 in the ODES sample yielded a mean seasonal willingness-to-pay of about 130 francs per visitor. This value represented the estimated loss, as a result of the oil spill, to each tourist who did come in 1978. Applying this unit loss to the estimated 2.07 million visitors who did come yielded an estimated loss of about 269 million 1978 francs.

The second set of questions probed how much insurance households would buy to reduce the risk of incurring losses in satisfaction in their vacations as a result of oil spills. Each respondent was given the option of specifying the amount of insurance he would purchase, for an oil spill occurrence of specified probability, under two conditions: (1) when he had to pay half the premium, which amounted to 2.5 percent of the amount of insurance purchased; (2) when he had to pay the full premium, which amounted to 5 percent of the amount of insurance purchased. Under the first condition only 23 of the 387 respondents would purchase any insurance at all; under the second, only 16 of the 390 respondents. The weighted mean amounts which would have been purchased per family were 310 francs and 125 francs, respectively, or about 80 and 35 francs per visitor. These represent the imputed unit losses as a result of the oil spill. Applying these unit losses to the estimated 2.07 million visitors who did come yielded estimated losses of 166 million 1978 francs and 72.4 million francs, respectively.

A final question was in terms of how many days of supplemental paid vacation would be required to induce a respondent who had visited the Brittany coast in 1978 to visit the same beaches in 1979 if the beaches were in the same condition as they had been in 1978. This question was posed to the sample of 390 tourists interviewed in the ODES survey in 1979. Forty-three percent of this sample, or 167, had visited the oil spill region in 1978. Ninety-three percent—all but eight respondents—said they would have come without receiving compensation of any additional days. Four of the respondents said they would not have come at all. The number of days is transformed into monetary units on the basis of the respondent's daily income. The resulting weighted mean compensation ranged from about 110 francs per person to about 30 francs, depending on what response was attributed to the respondents who said they would not come at all. The 30 francs figure was used as the estimate of unit loss. Applying this figure to the 2.07 million visitors who did come yields an estimated loss of about 62.1 million 1978 francs.

Residents. Although many residents of Brittany allegedly modified their recreational activities in 1978 because of the oil spill, specific evidence of what those modifications were, and the losses in satisfaction induced thereby, are virtually nonexistent. Only a rough indication of the possible magnitude of loss per family can be derived from the ODES survey, based on responses to the first insurance question.

Table 1-5.—Categories of Respondents in ODES Survey, Summer 1979.

	Polluted Region	Non-Polluted Region	Total
Tourists			
French	206	100	306
Foreign	54	30	84
SUBTOTAL (Tourists)	260	130	390
Residents	187	11	198
TOTAL	447	141	588

Of the 198 Brittany residents in the ODES sample responding to the first insurance question, 178 would purchase no insurance. Only 20, about 10 percent, gave non-zero answers. Depending on what was the largest amount of insurance specified as being available, the weighted mean amount residents were willing to purchase was either 580 francs or 440 francs per family. Assuming the respondents constituting the sample of the residents were representative of the attitudes of the families residing in the oil-damaged section of the Brittany coast, the unit value obtained in the survey could be applied to the number of residents to yield an estimate of the losses in satisfaction (social costs) in 1978 to residents because of the oil spill. Using the 440 francs per family figure and assuming a family size of four, yielded an estimated unit loss of 110 francs per resident.

The 198 residents responding represented a little less than one-tenth of one percent of the estimated 237 thousand residents in the coastal zone in Finistere and Cotes-du-Nord. Thus, the sample was very small, and there are no data on which to base any estimate of the direction and extent of bias in the responses, if any. Given the range in the estimates of unit loss to tourists who did come in 1978, from 3 francs per person to 130 francs per person, 110 francs per resident does not seem unreasonable as an upper limit to the unit welfare loss as a result of the spill. The lower limit is assumed to be zero. Applying these unit losses to the number of residents in the coastal zone yields estimated losses of 0 and 26.1 million 1978 francs.

Summary of Results. The estimated losses to recreationists range from about 50 to about 340 million 1978 francs, as shown in Table 1–6. This range reflects (a) the large range in estimated unit losses, and (b) the fact that there is no basis for proving that any one value is superior to all the others.

Problems

There were two major problems in estimating losses to recreationists. The first was the small size of each of the samples of tourists and residents, plus the exclusion of foreign tourists from the 1978 and 1979 INSEE surveys. There is no basis for knowing how biased the samples might be. Therefore, the extent to which they are representative of the total populations of tourists and residents is not known.

The second problem was the lack of exposure of Europeans to, and experience with, hypothetical questions. This point was stressed by knowledgeable European professionals when the analytical method was proposed. Under any circumstances extreme answers to hypothetical questions are very likely to be encountered and are even more likely when such questions are unfamiliar.

Implications

The primary lesson to be learned from the investigation of non-market losses associated with recreation is not that they are difficult to discover. This was known at the outset. Nor is the lesson the fact that there would be a wide band within which the monetary estimates of losses would fall. Anyone who has read or engaged in studies of this nature would have predicted that outcome with great confidence. The most important lesson is that if non-market losses are to be estimated, then preparations for making the requisite analyses must be made before the events occur. The following recommendations are based on what was learned in this study.

One, the most vulnerable and most valuable coastal and marine recreation areas should be identified before major spills occur. Developing this information would be costly, and it would probably be wasteful to collect data on all areas. Limiting areas initially studied to those of greatest vulnerability and greatest value would make good economic sense.

Two, the value of marine resource-dependent activities in these areas should be estimated. To estimate the longer term impact, i.e., 2–5 years, of an oil spill, normal rates of coastal tourism, its trends, and its determinants must be accurately ascertained. A rigorous attempt should be made to estimate the demand for marine-related activities in selected oil-spill-prone regions. Such an experiment would make clear what further data need to be collected in order to provide the level of accuracy desired of the demand estimates.

All practical techniques for estimating changes in behaviors of tourists due to an oil spill require knowledge of those affected by the spill. It is a fairly simple matter to determine places of origin, frequency of beach attendance, and other characteristics, if inquiries are conducted *before* a spill. After the fact, the appraisal is made very difficult and expensive because of the need to evaluate the varied responses to a spill. Some tourists will go to substitute coastal areas; some may instead vacation at different times of the year. Others will go to quite different regions, perhaps other countries. Economical and useful estimation of these second-best substitutes would be very much enhanced if preliminary studies had been made and standby capability existed to respond immediately when an oil spill or other type of marine pollution event which threatens marine-related activities occurs.

Three, these baseline studies should delineate what further data must be collected and codified in order to obtain answers of acceptable accuracy and to collect the missing data. Some of the shortcomings of the present study could be avoided if there were a spill along the U.S. coast, either because more data are routinely collected or they are more accessible. For example, records of those making hotel reservations or renting summer cottages or canceling commitments would probably be available in the United States for some number of months after the spill. These were not accessible in France.

Table 1-6.—Estimated Losses in Satisfaction of Tourists to, and Residents of, the Brittany Coastal Area Affected by the Amoco Cadiz Oil Spill.

Category of Individuals Affected	Estimated Number, (x 10^3)	Method for Estimating Unit Loss	Unit Loss (1978 FR)	Estimated Losses (1978 FR x 10^6)[a]
Tourists who did not come in 1978	245	Interviews with German tour operators	190	46.6 (11)
Tourists who came in 1978 but incurred losses in satisfaction	2,070	Travel cost: INSEE data	3	6.2 (1.5)
		Travel cost: ODES data	130	269 (64)
	2,070	Hypothetical insurance purchased	80	166 (40)
			35	72.4 (17)
	2,070	Extra days paid vacation	30	62.1 (15)
Coastal residents	237[b]	--	0	0
		Hypothetical insurance purchased	110	26.1 (6.2)
TOTAL LOSSES Minimum (lowest) estimate 1978 FR (x 10^6)[c]				53 (13)
Maximum (highest) estimate 1978 FR (x 10^6)[d]				342 (82)

[a] Figures in parentheses are U.S. dollars (x 10^6), based on 1978 exchange rate of 4.18 francs per dollar.
[b] Population of littoral zone in Finistere plus Cotes-du-Nord (Bonnieux, et al., 1980, Table 1).
[c] Minimum = Sum of minimum values in the three categories of the column.
[d] Maximum = Sum of maximum values in the three categories of the column.

Four, provisions should be made for collecting economic data immediately and systematically in coastal and marine areas damaged or threatened to be damaged by an oil spill or other type of marine pollution event. The present study failed to provide more accurate quantitative estimates of tourist losses because it began one year after the oil spill, i.e., one year too late. It began too late because public agencies were unable to respond and finance a study in time to obtain an accurate account of vacationers' behaviors as a consequence of the spill. It is just as imperative to collect data for economic analyses at the time of a spill as it is to collect physical data.

Plans and procedures for collecting data for economic damage assessment should be developed prior to an oil spill. If the spill occurs just before or during the tourist season, provisions must be made for an immediate response. Appropriate questionnaires will have to have been designed and tailored specifically to the various marine-resource user groups affected. Suitable survey research personnel will have to have been identified in advance and will have to be dispatched promptly if there is to be any hope of capturing the short-run economic consequences of an oil spill.

THE TOURIST INDUSTRY

The negative publicity following the Amoco Cadiz oil spill had a major impact on the perceptions of potential visitors concerning damage to the beaches of the region. From all accounts these perceptions of the effects of the oil spill had an impact on tourism in Brittany in 1978, especially during the early part of the vacation season, although poor weather was a factor contributing to reported declines in tourism during 1978.

A decline in tourism causes economic losses to those who supply goods and services to tourists, referred to collectively as the *tourist industry*. That industry is defined as the amalgam of hotels, guest quarters, campgrounds, restaurants, and other establishments that cater in whole or in part to tourists, and to some extent to residents engaged in similar recreational activities. In the short run, when a single oil spill is viewed in isolation, losses to the tourist industry of the affected region would occur to the extent that resources normally used by the industry, both capital—facilities and materials inventory—and labor, left unutilized by the decline in tourism, are not used in alternative economically productive activities or in the same industry at a later point in time. Certainly the flour, gasoline, wine, and film not used directly or indirectly by tourists who stayed away from Brittany in 1978 would all be used in alternative activities. Less clear is the situation for employees of the tourist industry in Brittany whose services were not needed. The services of labor are not storable, and workers may not be highly mobile in the short run. Nor are the capital facilities mobile, or likely to be suitable for other uses.

The losses to the tourist industry described above refer to losses realized within the region directly affected by the oil spill. The decline in tourism in Brittany was probably accompanied by increases elsewhere as tourists visited their second-choice destinations. Thus, losses to the tourist industry in Brittany were probably balanced by gains to the industry in other regions of France, in other countries, or both.

It should also be remembered that not all the consequences of the spill were harmful to the tourist industry. During the initial weeks following the spill, journalists and scientists from around the world converged on Brittany. Thousands of cleanup workers and at least hundreds, if not thousands, of curious onlookers spent time in Brittany. All of these people required services provided by the tourist industry. Therefore, losses to the tourist industry should be estimated net of any of these beneficial effects.

Some Characteristics of the Tourist Industry in Brittany

On the basis of data for 1979, Finistere is the most popular vacation area of the four departments in Brittany. It accounted for almost 40 percent of the summer visitors to the Brittany shore. Finistere and Cotes-du-Nord accounted for 60 percent of all visitors to the beaches of the region. Employment in the tourist industry is heavily concentrated along the coast, particularly in Finistere.

Most summer visitors to Brittany stay in second homes or rooms in homes, or in tents and caravans. In 1979, these categories accounted for about 85 percent of summer accommodations used. Only 8 percent of the visitors stayed in hotels. The amount spent by a household during a visit and the length of the visit varied with the type of accommodation. In July and August of 1979, the average expenditure per household per visit ranged from about 2.3 thousand francs to about 5.4 thousand francs; the average length of visit ranged from 23 days to 31 days.

Two facts are particularly important with respect to the estimation of losses to the tourist industry. One, only 62 percent of the active workers were salaried in 1975. The others were self-employed in owner-operated establishments. Two, tips and gratuities constituted a significant portion of income for employees in the tourist industry. These facts are important in modifying the results obtained from the analyses.

Data, Analytical Methods, and Results

Three analytical methods were used to estimate losses to the tourist industry. The first was based on estimating the decrease in total revenue to the industry and modifying that estimate to obtain a figure closer to the actual economic loss. The other two methods involved developing econometric models, referred to as the "pooled-time-trend model" and the "economic model," to estimate losses in real wage payments. Real wage payments were used as a measure of the level of tourist activity, because it was not possible to obtain a time series on tourist industry sales, value added, or other direct measure of output. From losses in wage payments estimates were made of both losses in labor earnings in, and losses in profits by, the tourist industry. Losses in profits were derived by using historical profit-to-wage ratios. Both econometric models allowed for offsetting effects of increased visitation during the period of cleanup and changes in recreation activities of local residents. The four industries analyzed with the two economic models were Retail Food Trade; Retail Non-Food Trade; Hotels, Cafes, and Restaurants; and Consumer Services.

Decrease in Revenue Method

As delineated in the previous section on recreation, it was estimated that about 245 thousand tourists did not come to Brittany in 1978 because of the spill. This number of visitors can be translated into the decrease in the number of households which did not come in 1978, using the average size of household by type of accommodation. Finally, applying the average expenditures per household by type of accommodation to the respective decreases in number of households yielded the estimated reduction of 240 million 1978 francs in tourist expenditures in 1978.

This estimated reduction must be adjusted to derive a more accurate estimate of economic losses to the tourist industry by taking into account offsetting gains during the period of cleanup; alternative uses of productive resources released by the tourist industry, both material and labor[16]; and additional losses because of reduced patronage by local residents. Adjusting for the first two factors yielded an amended estimate of losses to the tourist industry of 115 million 1978 francs. Lack of data with respect to the third factor precluded making any estimate of the resulting losses. Ignoring these losses means that the final estimate of 115 million francs is an underestimate by some unknown amount.

Loss in Wage Payments Methods

Because two of the methods for estimating losses to the tourist industry were based on losses in wage payments, it is important to understand the mechanisms behind such losses. An event such as the Amoco Cadiz oil spill reduces the demand for the output of the tourist industry, because of a reduction in the number of tourists. This in turn reduces the demand for labor in the tourist industry. The short-run response to that decrease in demand for labor can take one or both of two forms: (1) labor may be made unemployed; and (2) labor may be retained in the short-run but produce a lower output.

With respect to the first, about 60 employees in tourism-related businesses were reported fully or partially unemployed as of June 1978, as a result of the Amoco Cadiz oil spill (CODDAF, 1979).[17] Although there is no evidence that the spill led directly to widespread worker layoffs following the spill, the summer tourist season in 1978 did begin late and employers may have delayed hiring, or have hired fewer workers than they would have if the spill had not occurred. With respect to the second, workers in the Brittany tourist industry in the summer of 1978 did produce lower output per period and many received a lower effective wage. This point is especially relevant for waiters, waitresses, and other service workers who depend on gratuities from summer visitors for a portion of their income. With fewer visitors, workers in this category accommodate fewer customers and receive fewer gratuities per period, although the wage paid by the individual business does not change. This argument also applies to the owners of the many small, family-operated establishments in Brittany, which can be viewed as accepting lower. implicit labor earnings rather than shutting down.

The two econometric models were termed the "pooled time-trend model" and the "economic model." The former is so called because it uses *annual* data on real wage payments for the period 1968 through 1976 and *quarterly* data on real wage payments for the first quarter of 1977 through the fourth quarter of 1979. This model "explains" the behavior of real wage payments in tourist industries over the nonspill period as a simple function of time. The effect of the oil spill on real wages is estimated by the use of dummy variables for the second and third quarters of 1978. If the oil spill had an effect on tourism, the sign of the coefficients of the dummy variables would be expected to be negative and to be statistically significant.

The economic model "explains" annual real wage payments for the period 1968 through 1979 as a function of resident population in the relevant Brittany department, per capita real income in France, deviation in mean rain and temperature in the third quarter of each year for the relevant Brittany department, and a time trend. A dummy variable is used for 1978 to capture the effect of the oil spill on real wage payments in that year. Again, the sign on the coefficient for the dummy variable would be expected to be negative and to be statistically significant, if the oil spill had reduced tourism in Brittany in 1978.

The two econometric models were applied to the data on real wage payments for the four tourist industries specified previously for the departments of Finistere and Cotes-du-Nord, the two Brittany departments physically affected by oil from the Amoco Cadiz, and to the other two departments in Brittany, Morbihan and Ille-et-Vilaine, which were not directly affected by the oil spill. The outputs of the models represent losses in real wage payments. Various adjustments had to be made to these outputs in order to derive (a) losses of labor earnings and (b) lost profits.

The additional loss of earnings by self-employed workers was computed using national ratios for tourist industries separated into implicit wage and implicit profit components using the relevant profit-to-wage ratios. Further, estimates of losses in gratuities to employees in the Hotels, Cafes, and Restaurants industry were based on the assumption that gratuities equal 30 percent of wage payments, as suggested by Centre d'Etudes des Revenus et des Couts (1973, p. 37). Finally, the estimate of lost labor earnings was adjusted to reflect the opportunity cost of labor. It was assumed that the opportunity cost of the labor not used in tourist industries was 50 percent of the change in real wage payments.

Estimates of lost profits were based on profit-to-wage ratios for each tourist industry, by size of firm, at the national level. The national ratios for each industry were weighted by the size distribution of firms in each industry in the region, in recognition of the differences in the size structure of industries between the region and the nation. The estimated profit-to-wage ratios for the four industries varied by department, but averaged 1.2, 0.95, 0.56, and 0.63 for the Retail Food Trade, Retail Non-Food Trade, Hotels, Cafes and Restaurants, and Consumer Services industries, respectively.[18] These ratios were then applied to the estimated losses in wage payments obtained from the two models to derive estimates of lost profits.

The estimated losses derived from the two models were about 125 million 1978 francs for the pooled time-trend model and about 250 million 1978 francs for the economic model.

Summary of Results

Estimates of the losses of profits and labor earnings in the tourist industry as a result of the Amoco Cadiz oil spill were made by three analytical methods. To these costs was added lost regional income from ferry services to yield the estimated overall economic losses to the tourist industry.[19] The results are shown in Table 1–7.

Problems, Assumptions, and Limitations

Estimating economic losses to the tourist industry by estimating the reduction in tourist expenditures is both plausible and straightforward. The estimate is based directly on observed expenditure behavior by tourists to the Brittany coast. On the other hand, the two econometric models are based on wage payment data for industries which obviously serve residents as well as tourists. For these models the assumption is that all changes in wage payments in these industries—and in the associated economic losses—are attributable to the decrease in tourism in 1978 as a result of the oil spill.

The econometric models have three other major problems and assumptions. One, very few of the estimated coefficients are significant by any standard statistical test. The confidence limits in most cases include zero. That is, losses in the various tourism-related industries of the four departments could typically range from twice those estimated to no loss or even a small gain. The central values estimated are simply not very reliable indicators of actual losses.

Two, the profit-to-wage ratios used were computed from the ratio of total real profits during the period 1972–75 to total real wage payments for the same period. Just how well these represent conditions in a non-normal period, such as the oil spill period, is not known. A more relevant measure might have been the profit-to-wage ratio for a recession period.

Three, resources were not available to undertake a specific study of the opportunity costs of labor and capital in the tourist industry in Brittany. Based on the most relevant information available, an opportunity cost of 50% was assumed for both. The direction and magnitude of bias resulting from this assumption are not known. This limitation also applies to the first method used.

OTHER COST CATEGORIES

Discussion and estimates of most of the social costs of the Amoco Cadiz oil spill were presented in the previous sections of this chapter. However, a few categories remain to be discussed, namely, the values of the lost cargo and lost ship at the time of the accident; legal costs; expenditures on research relating to the oil spill; damages to agricultural crops; and damages to human health.

These categories of losses represent a diverse collection of public and private damages. Except for damages to human health, estimates can be made of their magnitudes using market prices. However, three problems exist. One, it was not certain—for some of these cost categories—exactly what fraction of the identified costs was incurred because of the Amoco Cadiz oil spill. For example, with respect to research on the fates and effects of the spilled oil, there was no objective way of determining what portions of the identified research budgets were directly related to the Amoco Cadiz oil spill.

A second problem involved unavailable data, e.g., in the case of legal costs, or insufficient evidence, e.g., in the case of damages to human health. A third involved the difficulty in knowing specifically when some costs were actually incurred. For example, research and legal costs have been incurred for more than three years since the spill. Other costs, such as those of the lost cargo and vessel, were incurred at the time of the accident. If it was not known specifically when costs were incurred, it was assumed that they were incurred in 1978. Thus, none of the estimates was discounted.

Table 1–7.—Estimated Economic Losses to the Tourist Industry in Brittany in 1978.

Category of Loss and Method of Estimation	Economic Loss, (1978 FR x 10^6)
Lost profits and labor earnings	
Estimated by adjusting loss in total revenues	115
Estimated by pooled time-trend model	124
Estimated by economic model	249
Lost income from ferry services	1.1 - 1.5
TOTAL ECONOMIC LOSSES	116 - 251 (28-60)[a]

[a] U.S. dollars (x 10^6) at 4.18 francs per dollar.

Value of Lost Cargo

Each of the approximately 220 thousand tons of crude oil lost from the Amoco Cadiz was reported to have been worth an average of about 454 francs on the world market at the time of the accident (Kiechell, 1979). Because only a small amount was recovered at the refineries where oily wastes from the cleanup were taken, the value of the entire cargo, i.e., about 100 million 1978 francs, was treated as a loss.

Value of Lost Tanker

A direct approach to valuing the lost tanker would have been simply to use the amount of hull insurance carried by the owner at the time of the accident, 63 million francs for the Amoco Cadiz. However, the office handling insurance for the Amoco Cadiz fleet stated that the value was considered to be 100 million francs (Flink, 1981). The actual social cost at the time was probably between these two values. Therefore, the former was used as the lower bound on the estimated social cost, the latter as the upper bound.

Legal Costs

Existing laws in the United States and France do not provide automatic procedures for assessing liability and costs of spills of oil or hazardous materials. Such determinations are usually made through complex adjudicatory proceedings involving extensive legal costs. Thus, an assessment of the social costs of the Amoco Cadiz oil spill should include the opportunity costs of the *additional* labor, capital, and any other resources used for legal purposes as a result of the spill.

However, standard practice in the legal profession results in treating legal expenses with strict confidentiality. Repeated attempts to establish at least a minimum figure for legal outlays by questioning a number of the attorneys involved in the Amoco Cadiz case met with no success. The only figure available was one released by the French government on the value of the contribution of the national government, in the amount of about 400 thousand francs, to some towns in Brittany seeking to recover damages from the spill. No additional figures were available, and there was no basis on which to make a more complete estimate. Because the total legal expenses are certain to be several or many times higher than this figure, but are not likely to be made public, a lower limit on legal costs was based on the known French expenditure, i.e., 400 thousand francs.

Research Costs

Almost immediately after the Amoco Cadiz oil spill, scientists of various disciplines from various countries converged on Brittany to take advantage of the opportunity to study the fates and effects of the spilled oil. As previously stated, the immediate objective was to assess physical, chemical, and related biological effects of the spill, i.e., effects on marine habitats and species. Soon thereafter research on the economic aspects was initiated.

The major sources of funding for the research were Standard Oil of Indiana (Amoco), the governments of France and the United States, and the European Economic Community. Several other nations, e.g., Canada, The Netherlands, and the United Kingdom, contributed unknown sums in support of various research projects. Expenditures on research were an estimated 15–16 million 1978 francs. About 85 percent was for natural science research; economic studies accounted for about 15 percent.

Damages to Agriculture

The Ministry of Agriculture confirmed that field crops near Roscoff were damaged by wind-borne mists during the height of the oil spill period and were later plowed under to avoid health risks. Cauliflower was the principal crop affected, but some spring potatoes were also affected. Additional crops were damaged in the process of moving equipment into the oil spill zone.

Compensation paid to farmers by the national government was the basis for the estimated social costs. This compensation amounted to about 49 thousand francs.

Damages to Human Health

The Amoco Cadiz oil spill directly exposed two groups of people: residents of the adjoining areas, exposed to volatile hydrocarbons released into the air; and volunteer workers, military personnel, and other public employees, subjected to respiratory contamination, direct contact with their skin, and involuntary ingestion of small quantities of petroleum during the cleanup operations. However, no coordinated formal study of human health effects was undertaken, and there was no central direction to the data collection efforts which were undertaken. The evidence on effects that was collected came from posterior clinical examinations and laboratory tests, with one exception. A group of nine residents of Alsace was examined before and after working in the affected zone.

The preponderance of the evidence obtained during the cleanup period—both from casual observations and from tests—was that there were no serious, adverse, short-term effects on human health from the oil spill. Similarly, reports from local doctors showed essentially no increase in clinical symptoms during the remainder of 1978. Of course, the question of long-term effects on local residents and cleanup workers from direct contact with the oil in both liquid and volatile states remains. The only studies found on the biological effects of crude petroleum—the cargo of the Amoco Cadiz—had been done on animals, and these had yielded inconclusive results (Bingham, et al., 1979; Holland, et al., 1979).

The conclusion based on the foregoing was that both short-term and long-term damages to human health from the Amoco Cadiz oil spill were negligible.

Summary of Other Costs

The estimated social costs incurred for the cost categories discussed in this section are shown in Table 1–8. The estimated total is about 179–216 million 1978 francs. The loss of the cargo of crude petroleum and the loss of the tanker itself are the two major losses, representing about 91 to 93 percent of the total.

DISTRIBUTION OF COSTS

As previously indicated, distributional effects—the incidence of gains and losses among individuals and groups of individuals—are important both politically and legally. The political consequences of events such as the Amoco Cadiz oil spill usually depend in large part on the pattern of losses and the claims of damaged parties. In this study, the social costs were estimated for four political/economic aggregates: Brittany, France, the rest of the world, and the world. For these aggregates, social costs were estimated for the categories previously discussed in this chapter.

The results of the analysis illustrate three essential points. First, the estimate of social costs to Brittany, *net* of compensation payments from elsewhere in France and from outside of France, indicates how much of the economic burden of the spill was borne in Brittany. Second, the estimate of total social costs to France is indicative of the level of compensation necessary to make the French state as well off as if it had never suffered the spill. Third, the estimate of distributional effects among Brittany, France, and the rest of the world illustrates how losses can vary widely, depending upon the boundaries that are chosen for the analysis. For example, a loss in tourism profits in Brittany is a cost to the region, but not necessarily a cost to France, if it is offset by an increase in tourism profits elsewhere within the country. Similarly, a net loss in local public revenues is a cost to the region, but not to the nation, if counterbalanced by an increase in such revenues elsewhere within France. A loss in a resident's welfare because of a perceived reduction in beach quality or the higher cost of going to a substitute site is a regional cost; but if the individual is from outside Brittany, the loss is a cost to France or to the rest of the world and not to the region. Similarly, a loss in tourism producer profits is a cost to the region when the tourist facilities are owned by residents of the region. If ownership is from outside the region, the loss is not a regional cost.

Table 1–8.—Summary of Estimated Social Costs for Other Cost Categories, Amoco Cadiz Oil Spill.

Cost Category	Amount (1978 FR x 10^6)
Value of lost cargo	100
Value of lost tanker	63-100
Legal costs	0.4[a]
Research costs	15.6
Damages to agricultural crops	<0.1
Damages to human health	Negligible
TOTAL COSTS	179-216 (52)[b]

[a] Lower limit, based on the only specific information available.

[b] U.S. dollars (x 10^6) at an exchange rate of 4.18 francs per dollar.

It is apparent from the above that not all regional costs are necessarily national or rest-of-the-world costs, and the reverse. The regional focus involves drawing an economic boundary around Brittany. Only those costs incurred by residents of the region are counted as regional costs; all other costs are ignored. In principle, the magnitude of the regional costs, if they could be measured accurately, can be viewed as the amount that residents of the region would have to be paid in order to be no worse off in economic terms following the oil spill than they were before the spill.

One additional point is critical. Whatever expenditures are made by a national government in connection with an event such as an oil spill, the residents of any given region are likely to pay that share of national costs represented by the share of national revenues obtained from taxes paid by residents and entities of the region. This share was estimated by the Institut National de la Statistique et des Etudes Economiques (1979) to be 2.7 percent. However, current research by Prud'homme (1981) suggested that this share is more likely to be between 3.5 and 4.2 percent. The reason for this is that the relevant INSEE statistics are allocated to the region in which corporations are registered, which tends to overstate the share of national taxes "collected from" the Paris region and to understate the tax contribution of other regions, because many companies have headquarters but no other activities in Paris.

Estimates were made of the distribution of social costs for each of the categories discussed above. The bases for the results follow.

- **Cleanup**: The best evidence available indicated that essentially all of the cleanup costs were ultimately borne by the French national government, as compensation payments. Therefore, the costs borne by Brittany reflected the region's share of national taxes collected, and were estimated to be 15–20 million 1978 francs. Costs to France were estimated to be 430–475 million 1978 francs. Costs paid by nations other than France were estimated to be about 15 million 1978 francs. World costs then would be 445–490 million 1978 francs. However, there were additional resources made available from outside France for which no cost information was available, and there were recorded gifts on the order of 2 million 1978 francs. Because it was not known to whom the gifts were paid, because it was not known whether or not the amount involved was already counted in one category or another of cleanup costs, and because the amount was small compared to total cleanup costs, no modifications were made to the estimated cleanup costs.
- **Marine resources**: The information available indicated that the national government made compensation payments for all except about 1.5 million francs in damages to marine resources. Using the percentages indicated above with respect to the share of national revenues from Brittany, and the remaining costs to France of 138.5 million francs, yields 6–7 million francs borne by Brittany. No costs were incurred outside of France. World costs then equalled the 140 million 1978 francs.
- **Recreation**: The losses in satisfaction to recreationists were distributed on the basis of the origins of the visitors, i.e., Brittany, France outside of Brittany, and locations outside of France. The results in millions of 1978 francs were Brittany, 3–53; France (including Brittany), 31–290; rest of the world, 22–52; world, 53–342. The ranges reflect the different methods of estimating unit losses, as discussed previously.
- **Tourist industry**: In allocating the social costs to the tourist industry, the estimate of those costs, 116 million 1978 francs, was based on a decrease in tourist expenditures. The loss to Brittany would be the entire 116 million francs, except for whatever fraction of the assets of the tourist industry in Brittany is owned outside of Brittany. Because most of the tourism-related businesses in Brittany are small, and are of types likely to be locally owned, the amount of non-Brittany ownership is assumed to be small, e.g., no more than 5 percent. Fractions of zero and 5 percent were used, giving losses to Brittany of 116 million and 110 million 1978 francs, respectively.

  Estimates of the origins of tourists and estimates of where the tourists who did not go to the spill zone in 1978 did recreate, led to the estimate that about 75 percent remained in France. Therefore, losses to France with respect to the tourist industry amounted to only about 29 million 1978 francs.

  Because the remainder of the tourists were assumed to have found alternative sites outside of France, the tourist industry of the rest of the world gained an amount equivalent to France's loss, i.e., 29 million 1978 francs. Thus, for the world, the net cost to the tourist industry was zero.
- **Cargo and tanker**: Because the tanker was not owned by a French firm, because the shareholders were probably widely distributed, and because information on where the insurance was written is lacking, it was assumed that the values of cargo and tanker were essentially costs to the rest of the world. France's share could be only very minor, and that of Brittany negligible.
- **Legal and research**: The only legal costs which could be identified, 400 thousand 1978 francs, were paid by France. Of the research costs identified, 4.6 million 1978 francs were paid by France, and 11 million by other countries. Total legal and research costs to the world then amounted to about 16 million 1978 francs.
- **Regional secondary effects**: As stated in the introduction, secondary economic effects represent only regional costs, because the reduction in activities induced in a region by a decrease in primary activities or in resources diverted to cleanup, normally represent gains in other regions. The secondary effects to the Brittany economy stemmed primarily from the reduction in the level of activity in the tourist industry. They were estimated by use of an input-output table of the regional economy developed by Mandart, et al., (1976). The total amounted to 25–26 million 1978 francs.

The derived distribution of estimated social costs is shown in Table 1–9. Emergency response/cleanup/restoration constituted the largest single cost component, followed by losses in satisfaction of recreationists, losses to the oyster-culturing industry, loss of cargo, and loss of tanker.

The distribution shown in Table 1–9 merits the following comments. One, essentially all costs of cleanup and of damages to marine resources in Brittany were borne by the French national government, through direct expenditures and through compensation payments. However, it must be emphasized that there are likely to have been both some costs for which no data were available and some for which no compensation was paid to Brittany. The amount is believed by the analysts to be small, i.e., less than 5% of the sum of the regional cost of the cleanup and marine resources categories.

Further, it is difficult to account unambiguously for the transfer payments, as noted previously, because many of the data were, and are, not public. As far as could be ascertained, virtually all of the payments indicated were in fact made to the region by the national government. In the absence of compensation payments, the burden of the costs associated with cleanup and losses to marine resources would have fallen heavily on the region. As it was, the residents of Brittany are assumed to have borne that portion of those costs in proportion to their tax payments to the national government.

Two, as noted at various places in the previous sections, some costs were incurred in years subsequent to the year of the spill. Not all of these subsequent costs could be accounted for in the analyses. This is particularly true with respect to possible long-run damages to certain marine resources, e.g., oyster culturing. However, these costs would probably represent a small portion of the total costs identified, and would be well within the accuracy of the estimated costs.

Three, losses to the tourist industry were the major social cost to Brittany. Losses in tourism profits and labor earnings are considerably less important for France as a whole. This fact follows from the high probability that most of the summer visitors who avoided Brittany's beaches in 1978 because of the perceived effects of the oil spill spent their vacations elsewhere in France. It follows that the secondary economic effects of the spill, which are mostly attributable to the tourist industry, are much smaller—probably negligible—for France than for Brittany, because the secondary losses to the region's tourist industry are offset by increases in the tourist industry in other regions of France.

Four, because it appeared likely that tourists who did not go to Brittany or to other areas in France in 1978 did go somewhere for recreation that year, the net social cost to the world with respect to the tourist industry is estimated to be essentially zero.

Five, the wide range in the estimates of losses in satisfaction (welfare) to recreationists reflects the limited data available for analysis, small sample sizes, and the unfamiliarity of Europeans with hypothetical survey questions.

The total net social costs of the Amoco Cadiz oil spill were estimated to be between about 800 million and about 1,200 million 1978 francs. The analysts are reasonably confident, i.e., 95%, that the net social costs of the oil spill amounted to one billion 1978 francs plus or minus 20% (between 800 and 1,200 million francs), or approximately 190–290 million 1978 U.S. dollars.

LESSONS AND IMPLICATIONS OF WHAT HAS BEEN LEARNED

Attempting to meet the two objectives of the study—namely, to test methodologies for estimating social costs and to estimate the social costs of an actual event, the Amoco Cadiz oil spill—yielded some insights into various problems of estimating social costs related to oil spills and similar events. This section is a discussion of some of the lessons and implications resulting from the effort. The remaining chapters of the report contain the details of the analyses of the different components of costs summarized previously in this chapter.

The Basic Problem

As pointed out above, it was hoped that it would be possible to estimate the benefits from each increment of the cleanup effort. This hope reflects the basic problem, namely, determination of the optimal program for spill damage reduction. The objective should be to minimize the total costs from oil spills (or from spills of any hazardous material). The total costs equal the annual spill avoidance or "readiness" costs + cleanup costs + remaining damages, i.e., those not prevented by the "readiness" activities and the cleanup activities. The first component represents the costs of procuring and stockpiling materials, e.g., dispersants, deemulsifiers, and certain equipment, such as pumps, skimmers, and booms, for use under spill conditions; the administrative costs of maintaining a spill response organization, including personnel training and contingency planning; and the costs of collecting data to establish baseline conditions and trends for various marine-related outputs and activities, e.g., fish catch, recreation. Structural modifications to tankers and barges and changes in navigation procedures could also be included in "readiness costs."

The first two components can be considered spill damage "prevention" costs. Because it is highly unlikely that prevention costs could ever eliminate all damages, some costs will always remain. In some cases, the cleanup measures themselves result in damages, e.g., from movement of heavy equipment or use of high pressure hoses for washing. The magnitude of the remaining damages, i.e., those which can be affected, is a function of the first two components. Thus, basic information which is needed to determine the optimal program is how much damage can be reduced by various combinations of readiness and cleanup activities. This in turn leads to at least three questions.

Table 1-9.—Distribution of Estimated Social Costs of the Amoco Cadiz Oil Spill.

Category of Costs	Costs (1978 FR x 10⁶)			
	Brittany (1)	France, Including Brittany (2)	Rest of the World (3)	Total Net Social Costs to World (2) + (3)
Cleanup	15-20[b]	430-475[b]	15	445-490[b] (106-117)[a]
Marine resources	6-7	140	0	140 (33)[a]
Recreation: tourists and residents[c]	3-53	31-290	22-52	53-342 (13-82)[a]
Tourist industry	110-116[d]	29[e]	-29[e]	0[e]
Other[f]	0	5	174-211	179-216 (43-52)[a]
Regional secondary effects	25-26	-	-	-
TOTALS	159-222 (38-53)[a]	635-939 (152-225)[a]	182-249 (44-60)[a]	817-1188 (195-284)[a]

[a] U.S. dollars (x 10^6) at exchange rate of 4.18 francs per dollar.

[b] The range reflects the two assumed residual values of capital equipment purchased, i.e., 50 and 75 percent.

[c] The range reflects the various methods for estimating the losses in satisfaction of tourists who did come in 1978 and of residents.

[d] The range reflects the two assumed proportions of tourist industry businesses in Brittany owned outside Brittany, i.e., 0 and 5 percent.

[e] The figures are based on the estimate that three-fourths of the losses to the tourist industry in Brittany were recouped by the tourist industry elsewhere in France; the other one-fourth represented a gain to the tourist industry outside France, in effect, a net gain for the "rest of the world." Thus, the net social costs to the world with respect to the tourist industry are essentially zero.

[f] Other includes loss of cargo, loss of tanker, legal costs, research costs, damages to agricultural crops, and damages to human health. The range reflects the two alternative estimates of the value of the lost tanker.

The first can be illustrated in relation to the Amoco Cadiz oil spill; i.e, what would the remaining damages have been if *no* cleanup activities had been undertaken? (Of course, another relevant question is, what would the remaining damages have been for different mixes and levels of cleanup measures?) Thus, even though it was not possible to estimate the benefits obtained from each increment of cleanup, at least a rough estimate of the benefits from the total cleanup effort could have been made. For example, what would the damages to oyster culturing have been if no attempt had been made to prevent oil from entering the estuaries? What would the losses to the tourist industry have been if there had been no cleanup of the beaches? In effect, the question is framed in terms of "with" and "without" cleanup.[20] As defined above, the problem would involve both components of prevention costs, i.e., readiness and cleanup.

A relevant analogy is to a flood damage reduction system comprising a flood warning subsystem; an evacuation/return subsystem; and flood proofing of various buildings. For a given pattern of activities in the flood plain, for any given magnitude-duration of flood flow, the operation of the flood damage reduction system, while having no effect on the flood flow, will reduce damages by some amount. Thus, in analyses of flood damage reduction programs, what is investigated is the extent of damage with and without various measures.

A second generic question relates to the problem of identifying the various physical measures that can be applied, for example, the use of skimmers, pumps, booms, chemical dispersants or coagulants, and characterizing their effectiveness under different sets of conditions, such as type of oil, location of spill, weather during and after the spill, type of beach, and coastline configuration. The associated capital and operation and maintenance costs must also be identified. These measures relate both to "readiness" costs and cleanup costs. The former in turn consists of: (a) those measures—and the opportunity costs they represent—specifically allocated to, and stored for, spill response activities, e.g., booms which have no other use; and (b) those measures (and *some proportion* of the opportunity costs they represent) which are used in other activities but are available on short notice for spill response activities, including military vessels and personnel, other public employees and equipment, and existing communications networks.

The third question involves the fact that all three components of costs relate to anticipated spills. That is, the *expected* value of spill costs for any given location is a function of the expected frequency, magnitude, and timing of spills. These factors, in turn, are a function of international trade and economic conditions, oil shipments and routes, tanker design, and operational procedures. For example, supertankers are known for their lack of maneuverability. However, use of these vessels appears to be on the wane for economic reasons. The last one was built in 1979, and 27 supertankers were scrapped in 1980 and 1981 (Anon., 1982). The widening of the Suez Canal to accommodate 150,000-ton ships makes use of the Suez Canal more economical than use of the current routes around Africa. Thus, the change in size and type of ships and in the routes for transporting oil will change the expected frequency of spills. This, in turn, will affect future expected costs of spills to those who use those resources which may be damaged or diverted by these events.

Estimating Costs and Damages

In terms of the cost minimization problem defined in the previous section, all categories of costs discussed in other sections of this chapter and in the following chapters, except cleanup, relate to the third component, i.e., remaining damages. These "remaining damages" comprise, for example, damages to oysters, open-seas fisheries, losses to the tourist industry, and lost cargo. This section contains, first, some concluding observations on cleanup costs, and then concluding observations on some of the categories of remaining damages.

Cleanup Costs

In general, estimating cleanup costs is relatively straightforward, most of them being incurred shortly after the event, e.g., within a year. Market prices can generally be used, but may require certain adjustments for imperfect market conditions. However, care must be taken to exclude transfer payments, such as value-added taxes. Difficulties arise in estimating the opportunity costs of (1) labor of volunteers, military personnel, public works employees, policemen, firemen; (2) military equipment used (whether simply on standby awaiting training exercises or diverted directly from military uses); (3) equipment purchases, during both previous events and the present event, where the equipment has utility for subsequent use, not only in responding to spills but in other public works operations; (4) supplies previously purchased for responding to events; and (5) longer-term expenditures made, e.g., after the year of the event. The first and second are discussed in detail in Chapter 2. Another question with respect to the second is whether depreciation of military equipment should be attributed to the event. Only if use during the event *accelerates* the depreciation of equipment purchased for other uses is attribution to the event justified. The third and fourth difficulties fundamentally boil down to an accounting problem. That is, if equipment and supplies purchased to be ready for events are included in the annual costs of the "readiness" program, their costs are easily estimated.

The fifth difficulty is also an accounting problem. Although probably 90–95 percent of the cleanup costs associated with an event are incurred within a year after the event, some expenditures may be made over a longer period. The Amoco Cadiz case is illustrative. For example, some beach access roads and parking lots, never meant to support the weight of the equipment used in, and the loads of materials transported from, the spill zone, deteriorated under the hard use. Some seawalls and boardwalks were damaged by the force of water from high-pressure hoses and the weight of pumping and transportation equipment. Expenditures on restoration of these facilities continued after the year of the spill. Similarly, efforts to reestablish dunes and grassy areas around equipment parking areas and work sites and restoration of temporary storage areas for liquid and solid wastes continued throughout the summer of 1979. For such longer-term expenditures the primary problem is that of separating *normal* operation and maintenance costs from spill event-induced costs.

Most of the problems in estimating cleanup costs would be eliminated if there were a continuous accounting system and a system of standard cost categories. Devising the latter is an analogous problem to that of agencies which have had long experience in keeping records on stochastic events, such as forest fires, floods, and hurricanes. In each case the cost associated with the event is available soon after the event, because of the standardized system developed for recording costs "under fire." An additional value of a standardized accounting system is that it would permit developing ranges of unit costs for different types of physical measures, which then could be used in at least preliminary estimates of readiness costs associated with proposed spill damage reduction programs.

Damages

There are three primary problems with respect to estimating damages: (1) uncertainties associated with the effects of spills on both the marine environment and human behavior; (2) lack of data; and (3) for at least two types of damages, lack of credible methodology for making estimates. Lack of data might be considered to subsume "uncertainties." However, the former involves knowing what data are needed, but having no mechanism to collect them in an orderly manner over time, e.g., hotel or campground registrations. In contrast, uncertainties involve a lack of understanding of the basic mechanisms involved. Examples of these three problems follow.

Marine Resources. The fundamental problem with respect to estimating costs to marine resources, such as oyster culturing and open-seas fisheries, is to be able to estimate when the resource will have returned to "normal" after being stressed by such an event as an oil spill. This is particularly difficult if there are longer-term trends, up or down, in the annual output of the resource, rather than a dynamic equilibrium with random perturbations around the mean. Estimation is somewhat easier for what is primarily an artificially controlled industry like oyster culturing, than for an industry like open-seas fisheries, whose outputs are controlled primarily by nature. There is substantially less randomness in production from year to year in the former than in the latter. Therefore, for some given set of conditions, it is substantially easier to estimate the expected level and variance of annual production for the former than for the latter.

Further, in the case of the Amoco Cadiz the spill affected habitat with respect to oyster culturing, as well as directly affecting oysters. It is far less clear what mechanisms affected by the oil were responsible for the estimated losses to the open-seas fisheries: effects on habitat; direct effects on fish, adults vs. young; or both. The simple regression analysis used to estimate losses to open-seas fisheries involved only time as the independent (determining) variable. An arbitrary end to the effects of the spill was chosen, i.e., the end of 1979. No attempt was made to differentiate spawning areas, feeding areas, migration paths by species, as was done for sea birds as described in the Appendix to Chapter 3. The outputs of econometric analyses should always be checked against the scientific knowledge of the phenomenon involved.

With respect to the oyster-culturing operations, the uncertainty is related to possible longer-run effects of the oil from the Amoco Cadiz still contained in the sediments in the estuaries. The oil, intermixed with sediment, has weathered slowly, and may have degraded into materials more toxic than the original oil. The most informed estimate at the time of study has turned out to be an underestimate of the time to return to normalcy. This problem is affected by such variables as the nature of the oil, the nature of the beach, and weather.

One other point merits emphasis. In the case of the Amoco Cadiz, the reduction in supplies represented by the decrease in output of the open-seas fisheries industry—and presumably even the oyster-culturing industry—were so small as to have had a negligible impact on supplies to the established markets. Substitute sources (other regions of France and the European Economic Community) readily filled the gap, so that effects on product prices were negligible. However, where an event will reduce output from the affected area such that a substantial segment of supply is eliminated for one or more years, and prices therefore are substantially affected, analysis of the demand side will be essential.

Recreation and the Tourist Industry. As with marine resources, the major problem is estimating both the expected level of activity *without* an event and the period of time for tourism to return to normal *after* the event. The expected level of activity is affected by multiple variables, including weather, economic conditions, availability of accommodations, social tastes, perceptions of effects of spills and frequency of spills, and information available. The effects of the first three on recreation/tourist behavior are straightforward; the effects of perceptions and information less so. People respond to their perceptions of the nature and likelihood of natural hazards and human accidents, as the literature on these events makes clear. Often their perceptions of the probability of occurrence have little relationship to reality, as has been shown so often to be true with respect to perceptions of floods. Similarly, individuals may have little understanding of how a spill can affect the recreation areas in which they are interested, not merely in the year of the spill, but in subsequent years. The combination of perceptions and available, *credible* information will affect the time pattern of responses, both immediate and longer-run, and hence the time before tourism returns to normalcy. The importance of accurate information was amply demonstrated in the Amoco Cadiz case by the responses of the German tour operators.

What is critical in estimating damages to recreationists and to the tourist industry is having the basic trend data, e.g., number and origins of visitors, length of stay, type of accommodation used, size of household, expenditures, and types of activities.

Noncommercial Marine Biomass/Sea Birds. The third problem, lack of a credible method for estimating damages, is exemplified by noncommercial marine biomass and sea birds. Although *physical* losses of both as a result of the Amoco Cadiz oil spill could be—and were—estimated, assigning economic values to those losses is a step for which credible methods do not yet exist. Yet the economic values of both can be "real." The noncommercial marine biomass provides critical input in terms of food for commercial species. Current attempts to develop a method for estimating monetary value are based on that fact. With respect to sea birds,

it is obvious that some individuals do value them and are willing to forgo some goods and services in order to be reasonably certain that the birds will survive indefinitely. Contributions to various organizations and agencies to "save" species and habitat are evidence of this attitude.

Needed Baselines and Simplified Methods

This cursory discussion leads logically to the conclusion that what is needed is a set of "baselines" or "baseline conditions," one for each of the relevant cost and damage categories. However, there are opportunity costs associated with collecting and analyzing data. Therefore, not all areas can be covered and not all types of data gathered. What is required then is a system for establishing priorities for data collection and analysis by ranking areas.[21] Criteria which could be used for ranking include susceptibility of fisheries to spills by time of year, importance with respect to economic value of fisheries, susceptibility of threatened or endangered species to spills, susceptibility of marine-related recreational activities to spills by time of year, economic importance of recreational activities, and probability of occurrence of significant spills. Some of the needed information is already available or is being gathered through the Environmental Studies Program of the Bureau of Land Management, the ecological inventories of the U.S. Fish and Wildlife Service, "environmental sensitivity index" mapping supported by NOAA's Office of Marine Pollution Assessment, and the Strategic Assessment Program of NOAA's Office of Ocean Resources Coordination and Assessment (ORCA). Ranking areas would ensure the most efficient use of the resources available for establishing baselines. Such baselines are relevant not only for estimating the social costs of oil spills, but also for estimating the social costs of other events, such as discharge of hazardous materials, ocean disposal of municipal and industrial sludge, routine discharges of oil from normal operations such as tank cleaning or ballasting, and the discharge of sewage through ocean outfalls.

Even with a selective data collection and analysis system which emphasizes the most critical areas, two additional inputs are necessary for the development of a national spill damage reduction program. These are (1) simplified methods for estimating damages and (2) simplified methods for estimating costs. The former are needed to estimate the damages reduced by any proposed spill damage reduction program and the latter to estimate the costs of any proposed spill damage reduction program. Cost data such as those accumulated in the study of the Amoco Cadiz oil spill can be used to develop *ranges* of unit costs for various physical measures. Similar ranges in unit damages reduced by various physical measures can be developed. These would provide a significant step toward the needed information base for management.

The following chapters describe in detail the background and nature of, and the methods for estimating, the components of social costs summarized in this chapter.

NOTES

[1]Tons refer to metric tons throughout the report.

[2]Departments are the smallest political units of the French central government. There are 95 such jurisdictions in France. For each department there is an administrative officer called a "prefect" who, as a representative of the French prime minister, coordinates policies of the central government at the local level. Communes are the smallest political jurisdictions within a department and correspond roughly to villages and towns in the United States. Cantons comprise several communes.

[3]The average monthly exchange rate in 1978 was 4.18 francs per dollar. This rate is used throughout the report.

[4]There may be some value associated with leisure time available to those involuntarily unemployed. How much is not known. The value probably varies substantially among individuals, particularly in relation to base salary, length of unemployment, and public assistance available.

[5]The total social cost also can be regarded, in principle, as the amount that would have to be paid in order to leave those affected as well off after the spill as they were before the spill. Technically, there is an important conceptual difference between an individual's willingness-to-pay to avoid damages from an oil spill and the amount that the individual must be paid in order to be no worse off after the spill than before. The two measures of welfare loss will be the same only if the effects on incomes are negligible. This will be true if the oil spill results in small changes in income. If individuals suffer large losses in income, the two measures will differ, and the compensation required will be greater than the willingness-to-pay of the individual.

The practical significance of this argument is that, in those cases where substantial losses to individuals result from a spill, there will be two different measures of welfare loss. There will be no single "correct" measure of damages even in theory. For example, the measure adopted will depend upon one's view of who holds the property right to a clean beach. This depends on social value judgements, not on economic principles.

[6]In principle an additional component should be included, namely, the alternative earnings of factors of production, e.g., labor, capital, boats, which normally would have been used to produce customary outputs of, e.g., fish and tourist services, but were not so used because of the spill. Because there appeared to be essentially no alternative productive uses of these resources, the alternative earnings are zero. If there had been alternative earnings, the amount would have *reduced* the net costs.

[7]Conceptually, some estimates of possible future uses of capital goods could be made. With respect to public works, often a moving five-year capital and annual operation and maintenance program is available for a region. Given the elements of that program, and the inventory of available equipment, potential uses of capital goods could be identified. With respect to future oil spills, the probabilities of spills of various magnitudes and in various locations could be estimated on the basis of the historical record and modified for estimated changes in tanker design, tanker traffic, and operating procedures. On that basis, the expected use of capital equipment in oil spills could be estimated.

[8]The same problem exists with respect to private entities. However, most of the cleanup costs involved in this case were incurred by public agencies/jurisdictions.

[9]These costs are analogous to flood damage reduction costs in the form of the annual costs of a flood warning-evacuation system.

[10]A quartier maritime is a regional division of the formal administrative structure for management of maritime affairs in France. The fisheries management segment of this structure is described in Chapter 3.

[11]Scallops are not an open-seas fishery in Brittany. The oil spill did not affect the harvest of scallops.

[12]The model allowed for the typical random variations in catch from season to season and year to year.

[13]Surveys by the Institut National de la Statistique et des Etudes Economiques, beginning in 1965, have found that visitors to the Brittany coast represent between 80 and 85 percent of the visitors to Brittany. On that basis the estimated 2.32 million visitors to the coast in 1979 imply between 2.90 and 2.73 million visitors to Brittany in 1979. This compares with the estimated mean number of annual visitors to Brittany for the period 1973–1976, from the above cited annual surveys, of 2.84 million (Secretariat d'Etat au Tourisme, 1977).

[14]The coastal zone is defined by the communes within each department which border the ocean or the English channel.

[15]Hereinafter The Federal Republic of Germany is referred to simply as Germany.

[16]Theoretically certain resources normally used in the tourist industry could be redeployed, lessening the economic loss. However, the economy of Brittany is not very diversified, so that there are few alternative employment opportunities in the short run. Further, the tourist industry in Brittany is characterized by a preponderance of small, family-owned operations. For these reasons, an opportunity cost of labor of 50 percent of market wages was assumed. For similar reasons, capital invested in the Brittany tourist industry is not mobile in the short run. Therefore, it also was assigned a relatively low opportunity cost of 50 percent.

[17]CODDAF is the Comite Departmental de Developpement et d'Amenagement du Finistere.

[18]The seemingly high ratios reflect the fact that what are recorded as profits for many small Brittany businesses with few or no salaried employees in fact are implicit wages.

[19]It was recognized that the industries included in the econometric analyses did not encompass all types of economic activities in Brittany that might have been affected by the decrease in tourism in 1978, such as transportation, e.g., railways, airplanes, and ferries. Sufficient data were not available to permit estimating losses to these activities with one exception, coastal and international ferry operations. The former involves the provision of harbor tours, transportation to the scenic islands off the Brittany coast, and travel along the coast. The latter involves transportation between Brittany and particularly England and Ireland. The lost income from these ferry services was estimated.

[20]A strategy which involved doing nothing, i.e, no cleanup and letting nature take its course, might be the one which *minimized* (net) economic costs to society. But there would probably be substantial political problems associated with such a strategy. Some degree of cleanup is likely to be necessary, whatever the cost, to demonstrate that the government is responsive and not ruthless. That the value of a simple sea bird still living two years after having been treated for effects of oil would have to be on the order of $1,000–$1,500 to equal the opportunity costs of treating it, based on the evidence presented in the Appendix to Chapter 3, is not likely to eliminate all pressure for action.

[21]See Owens and Robilliard (1981) for a comparable suggestion.

REFERENCES

Anonymous, 1982: Death of the supertanker. *World Press*, 29, 1 (January).

Bingham, E., R.P. Trosset, and D. Warshawsky, 1979: Carcinogenic potential of petroleum hydrocarbons: a critical review of the literature. *Journal of Environmental Pathology and Toxicology*, 3, 1&2, 483–563.

Bonnieux, F., P. Dauce, and P. Rainelli, 1980: *Impact Socio-Economique de la Maree Noire Provenant de l'Amoco Cadiz*, Institut National de la Recherche Agronomique, Rennes, France, 248 pp.

Centre d'Etude des Revenus et des Couts, 1973: *L'Hotellerie Francaise: Deuxieme Partie; Facteurs de Production et Rentabilite des Entreprises: Rapport de synthese* (3rd and 4th trimesters, 1972) Paris.

Comite Departmental de Developpement et d'Amenagement du Finistere, 1979: *Note de Synthese sur les Incidences Economiques de la Catastrophe de l'Amoco Cadiz*. Quimper, France (January).

Finkelstein, K., and E.R. Gundlach, 1981: Method for estimating spilled oil quantity on shoreline. *Environmental Science and Technology*, 15, 5, 545–549 (May).

Flink, M. (Insurance Manager, Standard Oil of Indiana, Chicago, Illinois), 1981 (personal communication).

Gundlach, E., and M. Hayes, 1978: Investigations of beach processes, in Hess, editor, *The Amoco Cadiz Oil Spill—A Preliminary Scientific Report*. NOAA/EPA Special Report, National Oceanic and Atmospheric Administration, Boulder, Colorado, 85–196.

Holland, J.M., R.O. Rahn, L.H. Smith, B.R. Clark, S.S. Chang, and T.J. Stephens, 1979: Skin carcinogenicity of synthetic and natural petroleum. *Journal of Occupational Medicine*, 21, 9, 614–618.

Institut National de la Statistique et des Etudes Economique, 1979: Statistiques et Indicateurs des Regions Francaises, Annexe au Project de Loi de Finances pour 1979. No. 298–299 des Collections de l'INSEE, serie R, No. 34–35.

Kiechell, W., III, 1979: The admiralty case of the century. *Fortune*, 99, 8, 78–89.

Mandart, C., H. Krier, and J. Kergoat, 1976: Les relations entre la Bretagne et l'exterieur: Le tableau d'ensemble des resources et des emplois regionaux de biens, in *Le Tableau Economique de la Bretagne*, Bulletin de Conjoncture Regionale Region de Bretagne, No. 3, Centre Regionale d'Etudes et de Formation Economiques, Rennes, pp. 115–149.

Owens, E.H., and G.A. Robilliard, 1981: Shoreline sensitivity and oil spills—a re-evaluation for the 1980's. *Marine Pollution Bulletin*, 12, 3, 75–78 (March).

Prud'homme, R. (Institut D'Urbanisme, Universite Paris XII), 6 April 1981 (personal communication).

Secretariat d'Etat au Tourisme, 1977: Statistique du Tourisme, No. 16, Quatrieme Trimestre, Paris, Table 2.

Vandermeulen, J.H., D.E. Buckley, E.M. Levy, B.F.N. Long, P. McLaren, and P.G. Wells, 1979: Sediment penetration of Amoco Cadiz oil, potential for future release, and toxicity. *Marine Pollution Bulletin*, 10, 8, 222–227.

Chapter 2

EMERGENCY RESPONSE, CLEANUP, AND RESTORATION

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INTRODUCTION

Although few comprehensive studies of the costs of oil spills have previously been undertaken, it is a widely held belief that the combined emergency response, cleanup, and environmental restoration activities—collectively referred to as "cleanup" in this report—represent the largest single component of the overall social cost of oil spills. The results of the analysis described in this chapter further support this view. The estimated 430–475 million 1978 francs (approximately 103–115 million U.S. dollars)[1] spent—in the year of the spill alone—by the French to clean up their coast, account for almost half of the total estimated social costs associated with the Amoco Cadiz oil spill. At least an additional 15 million francs (about 3 million U.S. dollars) were spent by foreign countries that joined the battle against the "black tide."

The cleanup costs associated with the Amoco Cadiz spill can be put into perspective by comparing them to the cleanup costs, adjusted to 1978 prices, of some other major oil spills. Cleanup costs for the Torrey Canyon tanker spill in 1967 were estimated to have been 180 million francs (about 45 million U.S. dollars); cleanup after the Santa Barbara Channel oil well spill of 1969 was estimated to have cost about 84 million francs (about 20 million U.S. dollars); and roughly 126 million francs (about 30 million U.S. dollars) were spent by Sweden, Finland, and the U.S.S.R. to clean up the spill of the tanker Antonio Gramsci in the Baltic Sea in 1979 (OECD, 1981). The estimated costs for the Amoco Cadiz cleanup operation alone are larger than the total damage costs estimated for any other single oil spill previously studied.

This chapter presents a detailed description of the estimation of the economic costs of the Amoco Cadiz cleanup effort. While the economic theory that has been applied to the problem is elementary, obtaining the necessary data for a complete cost estimate was a complex, time-consuming task. Though care was taken to obtain the best information available from the many sources that existed, inevitably there were some cost categories for which no data, or only partial or contradictory data, could be found. In such cases, the investigators either exercised their best professional judgement, or avoided attaching monetary figures altogether. Instances where simplifying assumptions or subjective judgements were applied are discussed in detail below.

The principal objective of this study was to develop and test analytical methods that would have general applicability in estimating the cleanup costs of future spills of oil and hazardous substances. It is believed that the success of any application of the methods described below will depend primarily on the availability of cost data and secondarily on the availability of productivity data.

Two additional objectives of the original study plan should be mentioned. One was to estimate the benefits of the cleanup effort, in terms of damages reduced or prevented. This objective remains largely unachieved for this spill, as well as for other spills that have been studied. The limiting factor is the inadequacy of the data on which to base an estimate, rather than the failure of economic theory to address the problem of estimating benefits or a lack of analytical methods. Yet, without a monetary estimate of the benefits of cleanup, it is impossible to determine an economic basis for cleanup efforts.

The other objective at the outset was to estimate incremental costs and related outputs, e.g., oil removed or area cleaned, for various cleanup techniques. This problem was more manageable than estimating benefits because of the availability of data on inputs and on cleanup productivity. As discussed more fully below, under "Marginal and Cost-Effectiveness Analysis," it was possible to measure how costs and output for certain cleanup activities changed over time. While these results in themselves do not lead directly to establishing better strategies for managing future cleanup operations, they do serve to illustrate (1) the need to understand better the concept and implications of cost effectiveness; (2) the importance of the concept in selecting the appropriate mixture of cleanup techniques from among the many alternatives available; and (3) how that mixture might logically change over the cleanup period.

COMBATING THE OIL SPILL

The French cleanup operation was guided by Plan Polmar, an interministerial oil spill response plan created in 1970, largely in response to problems encoun-

tered during the cleanup of the French coast following the Torrey Canyon spill. The plan was, and is, intended solely for implementation in the event of an actual spill.[2] In many respects it is similar to the U.S. federal oil spill contingency plan.[3]

The Amoco Cadiz accident severely tested the effectiveness of Plan Polmar in marshaling men and equipment to combat a major oil spill. Because the pollution and the public protests that followed it threatened public and private property and human safety, several thousand military personnel and pieces of heavy equipment were dispatched to the scene. As the oil moved northeast along the Brittany coast, spill response teams sought to establish defensive positions. Booms were deployed at selected locations, clean sand was removed, for protection, from some of the popular tourist beaches, and various chemicals were applied to the oil slicks at sea.

Operations under Plan Polmar were divided into two separate but parallel components soon after the Amoco Cadiz cleanup work began: Polmar-Mer for activities at sea; and Polmar-Terre for activities on land.[4] Within a short time, the cleanup operation had taken on the appearance and urgency of a major disaster relief effort.[5]

Plan Polmar-Mer

Operational responsibility for Plan Polmar-Mer was given to the prefect of the third maritime region (Prefet de la 3*ieme* Region Maritime). The French Navy's first major operation following the grounding was the evacuation of crew members in the early morning hours of March 17th. Later that day, nine naval vessels were dispatched to the area while others were prepared for eventual duty. Efforts to remove remaining cargo from the Amoco Cadiz proved infeasible because of the stormy seas and the difficulty of navigating an offloading vessel among the rocks surrounding the wreck. For the duration of Plan Polmar-Mer, the Navy's efforts were confined to spreading dispersants (about 1,300 metric tons were eventually used) and other materials on the oil at sea, monitoring the movement of the spill, controlling marine activities around the wreck site, and overseeing the transportation of oily wastes by ship.

Dispersants were spread on the slicks to increase the surface area between the oil and water and thus accelerate evaporation and biodegradation. However, the French believed that the dispersants could be harmful to marine life and therefore restricted their use to areas where water depths exceeded 50 meters. Because the Amoco Cadiz was aground in an area with a water depth of less than 50 meters, the oil slicks in the immediate vicinity of the accident site were not treated.

The French Navy also treated the floating oil with absorbent compounds in an effort to agglomerate the oil at sea to stimulate deposition and to facilitate recovery on shore. For example, a small quantity of chalk was used as a sinking agent to protect the Bay of Brest when oil slicks began to move towards its entrance.

Because the oil was being released gradually from the stricken tanker, the spill actually extended over a period of twelve days, with the result that previously cleaned coastal areas were often subjected to reoiling. Bombing the tanker on March 29th emptied the remainder of the cargo and fuel, bringing an end to the release of oil.

For oil recovery at sea, Plan Polmar-Mer was not very productive. High seas, strong winds, shallow waters, and limitations on the use of dispersants all impaired the Navy's ability to contribute significantly to the collection and removal of oil. Instead, the Navy's most useful activities appear to have been those of maintaining orderly marine traffic in the spill zone and monitoring the movement of the oil slicks along the coast.

Plan Polmar-Terre

Operational responsibility for Plan Polmar-Terre was given to the prefects of the four affected departments, Finistere, Cotes-du-Nord, Ille-et-Vilaine, and Manche. Only two departments, Finistere and Cotes-du-Nord, were directly affected by the spilled oil. Ille-et-Vilaine and Manche, located northeast of the spill zone, made contingency plans and prepared men and equipment for duty should the oil reach their shores. However, the oil never did strike that part of the coast.

In Finistere and Cotes-du-Nord, policemen, firemen, and employees of the French Ministry of Environment were joined by local farmers and public works personnel in the initial bucket brigades and booming and pumping operations. French officials decided that more manpower would be needed; therefore 3–4 thousand military personnel were dispatched to the spill zone. The first military personnel began arriving about a week after the accident. While it was not a prescribed function of the military to participate directly in land-based cleanup operations at the time of the Amoco Cadiz accident, military personnel eventually became the chief source of manpower for combating the spill. The first few weeks of Plan Polmar operations coincided with university Easter holidays, and during that time nearly 2 thousand students were accepted as volunteer workers. When the university holidays ended, the number of volunteer workers fell to a few hundred. In addition, French Red Cross workers provided health care for the cleanup crews, and police helped to maintain orderly vehicular traffic around the work sites.

To feed and house the several thousand cleanup workers coming from outside the region, schools, summer camps, and tourist hotels were converted to temporary barracks. Some operators converted voluntarily, while others were required to convert under orders from the prefects. According to officials in the prefects' offices (prefectures) in Finistere and Cotes-du-Nord, the furnishings and interiors of some of these facilities required extensive cleaning and rehabilitation after the cleanup crews had departed.

Booms were deployed as one of the first onshore responses in an attempt to protect the most valuable coastal resources. Some 20 kilometers of booming material were theoretically available in France at the time of the spill, but only about 11 kilometers were reported to be in good condition and usable. This quantity was insufficient to protect all ecologically sensitive and economically important areas, because the oil was threatening several hundred kilometers of coastline. Thus, the booms were deployed selectively, i.e., across the estuaries of Wrac'h and Benoit, the Bay of Morlaix, and a few other key locations. Booms placed across the two estuaries were not very effective, because strong tidal currents exceeded the design capacity of the equipment and pushed the oil underneath the booms. Later the booms failed completely, breaking apart in strong seas and high winds. This scenario was repeated in most areas where the booms were tried.

The oil that washed ashore was in the form of an emulsion averaging about one part oil to 2.5–3.5 parts water, or about 20–30 percent oil (Hann, et al., 1978). This material, commonly known as "mousse," was relatively fluid immediately after the spill, but it quickly became highly viscous and thus more difficult to pump as it aged. The normally high spring tides occurring at that time of the year, combined with unusually large wind-driven waves, caused significant quantities of mousse to be deposited high up on beach faces, tidal flats, seawalls, and rocks, and deep into the estuaries. The areas most heavily coated were westward facing beaches, and the seaward shores of barrier islands, estuaries, and marshes. The quantity of oil reaching the coast was estimated to be 60–65 thousand tons, or approximately 30 percent of the total amount spilled (Gundlach and Hayes, 1978), as shown in Figure 1–3. The remaining 70 percent became dispersed throughout the water column, was incorporated in bottom sediments, or evaporated or oxidized from the water surface. Approximately 245 thousand tons of mousse were eventually deposited along approximately 400 kilometers of coastline, enough to fill about 17 thousand railroad cars, each with a capacity of 8 thousand gallons.

Geomorphology and coastal processes, e.g., tidal and wave action, played major roles in determining where and to what extent the mousse was deposited on land. Local sinks, such as small bays, scour pits, joints and cracks around rock formations, marsh pools, and sand bar troughs, tended to trap the mousse. The combination of wave and tidal action is believed to have resulted in considerable self-cleaning along rocky headlands and high energy beaches. While helpful in washing areas not readily accessible to cleanup crews, this process also caused reoiling of previously cleaned areas as the refloated mousse came ashore. This problem was particularly acute for the first several weeks after the spill. Those areas above mean high tide received little natural cleaning by wave action after the spring tides and storms diminished. In the intertidal zone, stranded mousse typically became sediment-laden after repeated lifting and redeposition due to tidal flux and wave action. If not removed quickly by the cleanup crews, the mousse became dispersed in nearshore areas or buried under new sediment deposits. In some places, oil believed to have come from the Amoco Cadiz was found to a depth of 70 centimeters below the surface a few weeks after the spill (Gundlach and Hayes, 1978).

Large quantities of floating mousse were recovered from near-shore waters by vacuum pumping trucks that were brought in from all over France and from as far away as Belgium and The Netherlands. The vacuum trucks were highly effective during the early days of the spill, when the mousse was still fluid and freely floating at high tide. However, for the most part they were limited to operating on firm foundations, such as piers, boat ramps, and roadways. Where the terrain was too soft for the vacuum trucks, farmers pumped liquid wastes into pig manure tank carts or "honey wagons," each of which consists of a 750-gallon tank mounted on wheels with an integral, self-propelled pump. The honey wagons were towed behind farm tractors and were widely used during the entire pumping operation. Also, a large number of hand tools, buckets, and portable pumps were used to collect mousse in hard-to-reach areas.

Approximately 15 different skimming devices, some of which had proved sucessful in combating previous oil spills, were tested on the floating mousse. However, the effectiveness of these devices was severely limited by high seas and by seaweed that blocked pumps and hoses. Small "oil mop" skimming units proved effective when operated at high tide in the estuaries. However, skimming devices in general were much less useful than portable pumps, honey wagons, and vacuum trucks. In terms of volume of oil removed, pumping represented by far the most important technique.

Attempts were made to decant the water fraction and to break up the mousse chemically as the trucks, wagons, and portable storage tanks were filled. Nevertheless, significant quantities of water were taken with the mousse to interim storage areas near the work sites. These temporary storage facilities consisted of shallow, plastic-lined trenches in the sand or large portable metal cisterns. As the trucks and wagons discharged their loads, the fluids were pumped through baskets to strain out seaweed and other solid matter.

Once most of the floating mousse had been removed, the cleanup effort shifted to washing beach faces and structures and removing polluted solids such as seaweed and sand. This shift occurred only gradually. Indeed, it was difficult to associate a definite time period with any single type of cleanup activity, because activities changed frequently depending upon the available resources and the priorities that were set by the prefects and their advisers. According to personnel at the Centre de Documentation des Recherches et d'Experimentations sur les Pollutions Accidentelles des Eaux, in Brest, the highest priority areas were tourist beaches, fishing piers, sea walls, estuaries, and salt marshes.

After decanting, most of the mousse was trucked to railway tank cars and small tank ships for transportation to refineries in southern Brittany and Normandy. A small amount of mousse was also taken to a waste oil processing facility in Brest. The need to add demulsifying chemicals to the liquid wastes proved to be a continual problem during the month-long pumping, loading, and transport operations. Failure to add chemicals risked the possibility of solidification of the decanted mousse during transport. This occurred in some of the railway tank cars sent to a refinery in Le Havre in which the decanted mousse had not been treated with emulsion breakers. The honey wagons also proved exceptionally difficult to empty if emulsion breakers were not added during loading.

A layer of clean sand was scraped from several of the more popular tourist beaches before the oil arrived. The clean sand was reapplied after the danger of reoiling was past. For other beaches, there was neither time nor equipment to remove a layer of sand before the mousse came ashore.

Between 5 thousand and 10 thousand workers were engaged at various times in collecting oiled seaweed and detritus and placing it in plastic bags or in front-end loaders. Solidified mousse was picked up by men with shovels and buckets, sometimes aided by front-end loaders or short booms dragged over flat sand surfaces between two tractors. On some beaches, trenches were dug to collect oil flowing down the beach faces and to facilitate separation of the solids from the oil emulsion. The liquid wastes were then pumped into the honey wagons and taken to intermediate storage pits before being transported out of the spill zone. Natural cleaning of the beaches by tidal action was promoted by harrowing the sand with tractors.

Sorbent products tested on beaches near Portsall included sawdust, vegetable fibers, leather scraps, rubber powder, polyurethane foam, plaster, pinebark, perlite, and shredded paper strips. Following these tests, rubber powder was recommended for use in Finistere. Simultaneously, experiments were conducted with various chemicals to promote the biodegradation of oil trapped in the sand. Because the results were inconclusive, these agents were not widely used.

For pebbly beach areas, cleanup was complicated because the mousse passed between the pebbles and cobbles and became trapped at considerable depths below the surface. Because pebbly beaches were not particularly popular with tourists and because mechanical and hand cleaning were tedious, cleanup efforts were generally limited to bulldozing the oiled rocks onto exposed tidal flats and allowing the incoming tide and wave action to scrub and redeposit them throughout the intertidal zone. This technique proved particularly effective where wave action was most vigorous, such as on unprotected, seaward facing beaches and spits.

Hoses with a typical pressure of 7 kilograms per square centimeter (kg/cm^2) were used at first to wash the initial layer of oil from beach surfaces, large rocks, and structures. Subsequently, high pressure equipment of 400 to 900 kg/cm^2 was used. This high pressure equipment was not only expensive but also proved damaging to concrete structures and dangerous to operators. About two months after the spill, medium pressure hot water pumps were brought in, operating with freshwater at a pressure of 140 kg/cm^2 and temperature of 80°C to 140°C. These pumps proved to be quite effective and were cheaper and safer to operate than the high pressure equipment.

Initially, one man could clean about 500 square meters (m^2) of surface area per day using hot water washing techniques. However, by the end of the cleanup operation, the surface area cleaned had fallen to 20 to 50 m^2 per day (Bellier, 1979). Dispersants were used to prevent the loosened oil from readhering to the cleaned surfaces. Frequently, oil removed from the coated surfaces was simply allowed to seep into the sand or to wash out with the next tide.

Ecologically important areas, such as marshes, estuaries, and river banks, proved to be the most difficult areas to clean. While most oiled marsh and estuarine sediments were washed with hoses, some places such as Ile Grande marsh were cleaned by removing the oiled grasses and substrate with heavy equipment. The heavy oiling, up to 30 centimeters thick in places, combined with limited natural flushing and the damage from the cleanup operation itself, may cause these areas to take many years to recover. In 1980, much of Ile Grande marsh still resembled a barren moonscape. Very little biological activity was evident, and patches of asphalt-like material were liberally scattered throughout.

On river banks and in other areas characterized by soft sediments, men and equipment could be brought in only with great difficulty. The Wrac'h and Benoit estuaries posed special problems, because access to the oiled shorelines was limited to the few existing entry roads. These estuaries were intensively used for oyster culturing at the time of the spill. The sediments in both were still heavily contaminated with hydrocarbons three years after the spill. Normal biodegradation works slowly in these areas, because the contact of oxygen with the oil is limited. Consequently, discussions have been held regarding the feasibility of removing the sediments, or plowing them to promote greater exposure to oxygen.[6]

After interim storage near the cleanup sites, solid materials were taken to final disposal areas in Brest and Tregastel, and the equipment used in the operation was cleaned. About 30 thousand tons of the most liquid of the solid wastes were stored in five large plastic-lined pits dug near the harbor of Brest. About 100 thousand tons of solid material—sand, seaweed, and debris containing about 5 percent oil—have been stored near Brest and 40 thousand tons of similar material near Tregastel.

The most expedient method of treating oily solid wastes was to mix them with quicklime, creating an inert solid material. The long-term stability of the product is un-

known, but its low oil content and the oil-absorbing properties of quicklime should make the material acceptable for landfill.

The final phase of cleanup was the restoration of natural areas and man-made structures damaged by the cleanup activity. Heavy equipment and human traffic had caused significant damage to sand dunes, marshy areas, and the upper reaches of some beaches. In addition, beach access roads and parking lots, never meant to support the weight of the equipment being used and the loads of materials being transported from the spill zone, deteriorated under the hard use. Some seawalls and boardwalks also were damaged by the force of water from high-pressure hoses and the weight of pumping and transportation equipment. Efforts to reestablish dunes and grassy areas around the equipment parking areas and work sites continued throughout the summer of 1979. In some cases, roads, walkways, and seawalls were completely rebuilt. Temporary storage areas for the liquid and solid wastes also required considerable effort to return them to their pre-spill states.

In a limited way, cleanup and restoration are continuing, an example being the efforts to deal with the oiled sediments in the estuaries and marsh areas. Also, worldwide scientific interest in the ecological effects of the oil spill continues, as noted in Chapter 6. Several domestic and foreign universities and scientific organizations are conducting a broad range of studies on its chemical, biological, and social impacts.[7]

METHODOLOGY FOR, AND PROBLEMS IN, ESTIMATING COSTS

Cleanup activities following the Amoco Cadiz spill represent the largest category of direct spill-related expenditures by the French government. An overall assessment of economic damages must address the magnitude of the total cleanup expenditures, inasmuch as economically valuable resources were expended and alternative outputs forgone in the attempt to ameliorate the effects of the oil spill. One could view cleanup expenditures as an indication of what the French administration believed the citizens of France were willing to pay to mitigate the adverse consequences of the spill. Resources of other countries also were expended as part of the spill cleanup, monitoring, and control effort. Such contributions can be seen as expressions of what these countries were willing to pay to assist the French and to acquire information on the fate of the spilled oil. Cleanup costs will be measured in terms of opportunity cost, that is, the value of what was given up to acquire the goods and services used in the cleanup. Where competive markets exist, market prices provide the appropriate measure of opportunity cost. As will be discussed below, imputed values had to be developed for a variety of cost categories for which competitive market prices were not available.

In terms of who bore the costs, cleanup expenditures can be analyzed much like the other components of costs.[8] Most expenses were met by Plan Polmar at the ministerial level, indicating that most of the cleanup costs were borne by the French state collectively. Some costs were borne almost entirely within the Brittany region, for example, the unreimbursed costs incurred by local communes and the services of volunteers from the region. A minor portion of the cleanup expenditures was paid by other western nations as part of a collective effort to control and monitor the oil spill.

A number of groups and individuals contributed to private gift funds established under government sanction to help finance portions of the cleanup. Donations reportedly were received from throughout the world, though a majority is believed to have come from French sources. The gifts represent transfers of wealth that were used to finance real expenditures for goods and services not generally reimbursed by the French state. For example, they were used to pay for much of the environmental rehabilitation work undertaken after the Amoco Cadiz Plan Polmar operation was officially deactivated. Gifts should be treated as additions to total outlays under Plan Polmar. However, under French law, the amounts and sources of most of the donations were treated as privileged information, rendering a complete accounting for these expenditures infeasible.

Some Problems in Estimating Costs

Several empirical problems were encountered in measuring the economic costs of cleanup. For example, were market prices charged by the suppliers of materials for the cleanup, or did some suppliers raise prices during a period of temporary scarcity thereby earning short-run excess profits? If excess profits were earned, expenditures for these goods would not accurately reflect the true social opportunity cost of the inputs.[9] Prices for the labor services of military personnel and volunteers cannot be observed from normal labor market transactions. Thus, an approximation of their opportunity costs had to be developed. Further, capital goods that were purchased for use in the cleanup should be assigned a cost that reflects the residual value for use in other public works projects, including subsequent oil spills. Last, the costs reported by the French administration include value-added taxes (VAT), an item that does not represent an actual resource cost to the French state, because it is simply a transfer of funds. Accordingly, adjustments in reported costs were made whenever the VAT was included.

Before turning to these issues and the estimation of the total economic cost of cleanup, it is useful to reflect upon some related issues that are of interest. For example, the assignment of priorities in cleanup and the optimal extent of cleanup are topics of interest to oil spill response personnel and to politicians worldwide. The narrative discussion in the previous section allud-

ed to the process through which priorities were established in the Amoco Cadiz cleanup effort. Whether or not the result was in fact the best (social optimum) ordering of the response is an issue of concern to many. Likewise, whether more or less cleanup effort, and what type, should have been conducted on various stretches of shoreline will probably be debated for some time to come. Unfortunately, an analysis of marginal economic benefits and costs, which is necessary to establish what a socially optimum cleanup response would have been, was not possible. At best, the data permitted only an estimate of incremental costs per day for each department, and possibly an indication of the relative costs of certain types of cleanup techniques. It was difficult to derive accurate estimates of the incremental costs for separate cleanup activities,because the available records did not identify the work assignments or outputs associated with separate operations. Perhaps more important, adequate data were simply not available for estimation of the benefits of (damages prevented by) the cleanup effort. The aforementioned practical difficulties dictated that the analysis in this study be limited to an estimate of total economic costs of cleanup and a partial estimate of marginal costs.

Excess Prices

Prior to 1978, the French administration invested in equipment and supplies for Plan Polmar and predecessor arrangements to combat oil spills off the French coast. Despite those precautionary measures, the Amoco Cadiz spill created such an enormous demand for equipment and supplies that only a portion of that demand could be met from existing inventories. To guard against being charged prices that would give excess profits to sellers, the French government set maximum prices that would be paid for goods and services purchased for Plan Polmar. These prices were for the most part set at prespill levels. Inspection of the bills that were approved for payment by the prefects revealed no evidence that prices in excess of the government-set prices were in fact charged, nor was there evidence that these prices were so low that it became difficult to acquire the necessary goods and services. Thus, this study uses actual prices paid by the French government for equipment and supplies, unless otherwise noted.

Valuing Non-Market Services

The pricing of non-market services is an important issue when estimating labor costs for military personnel, volunteers, public works employees, firemen, and policemen. A number of alternative proposals have been advanced for valuing the services of military personnel. One proposal is that draftees be assigned an opportunity cost of zero, inasmuch as they would probably add only to unemployment were they not in the armed forces, given the surplus labor market in France. Likewise, it has been proposed that the cost of other military personnel, career and civilian, could be assigned a value close to zero, because few if any valuable outputs were forgone while they were at work on the spill. Certainly one would be hard pressed to argue that France's national defense suffered because of the involvement of the military in the cleanup operation. However, there is no hard evidence either to support or refute such a claim.

Nonetheless, the involvement of the military in the cleanup effort may have had a negative effect on some training programs. By some accounts the Army consumed a large fraction of its yearly allotment of fuel during the cleanup, thereby adversely affecting its ability to engage in full training schedules in 1978 and 1979. In addition, whether the conceptually correct measure of a draftee's worth is his productivity in alternative employment is also open to question. It is always the option of unemployed individuals to enjoy their leisure; this undoubtedly has a greater value to many draftees than does serving in the military. Thus, a correct measure of the costs of the draftees is more likely to be given by the wage that would be necessary to staff the military with volunteers. Unfortunately, this wage level is not known, because only a portion of Army personnel consists of volunteers. The reduction in value of other military outputs occasioned by the involvement of military personnel and equipment in the cleanup operations is also unknown.

An alternative perspective on the opportunity cost of the military is that responding to social emergencies, such as major natural disasters and rescue efforts, is one of the implicit roles of the military. In the long run, the size of military budgets and level of manpower probably depend, at least in part, upon the need for such services. Thus, oil spill response could be viewed as a responsibility of the military, one for which career personnel are paid and for which draftees are inducted. The major difficulty lies in imputing costs to an activity that the military engages in only on a highly irregular basis.

In the present analysis, the following position was taken. While military personnel, both career personnel and draftees, were engaged in the cleanup effort, salary, lodging, transportation, and other related expenses were incurred. The wages received by career personnel, and an imputed value for draftees (estimated as the average wage rate for unskilled labor in France), are indicative of what military personnel could have earned in alternative employment. The presumed labor opportunity cost, plus lodging and other living expenses and transportation, constitute the measure used to reflect the labor costs associated with military personnel. Whether the losses in national defense capability and the well-being of the draftees are accurately measured by this approach is open to question. Nonetheless, it is not felt that a more accurate approach existed, given the available information.

Another large category of labor input was provided by the Ministry of Environment, through its Department of Equipment (Direction Departementale de

l'Equipement (DDE)). DDE workers are normally engaged in such public works activities as the construction and repair of highways and the maintenance of parks. A reasonable argument can be made that the use of DDE personnel in the cleanup meant that other public works were sacrificed, at least temporarily. Therefore, wages paid, plus bonuses, and the costs of lodging, food, and supplies were assumed to approximate their social opportunity costs. The same procedure, based on the same rationale, was used to estimate the opportunity costs of firemen and policemen involved in cleanup.

Employment conditions are important in the pricing of volunteer services. Volunteers were drawn largely from student populations, with the majority serving during the Easter vacation in 1978. Many of these students normally would have been able to find short-term employment during the Easter holiday period at about the minimum wage in sectors with seasonal patterns of employment. The fact that these individuals volunteered for cleanup work may indicate that the income sacrificed was not a very important consideration or that there were some psychic benefits from participation in the cleanup effort. This would suggest that volunteer labor could be valued at less than the minimum wage rate for the type of work they would otherwise have done. However, it can also be argued that the opportunity cost of a student's time is higher than the minimum wage. Were they not in school, they probably would have been earning salaries that on average would have been in excess of the minimum wage, because students, by definition, have the capacity for working in highly skilled jobs. Because there is no empirical evidence to support either of these positions, the minimum wage rate plus transportation and living expenses were used to approximate the opportunity cost of the volunteers.

Valuing Capital Goods

The proper measure of the opportunity cost of capital goods that were rented or purchased during the cleanup operation is an issue without an unambiguous resolution. Conceptually, capital goods should be valued at their market prices; this was the convention adopted. However, there is one major problem in applying this approach.

As mentioned previously, the French administration had accumulated a stockpile of booms, pumps, and supplies for use in combating oil spills. When these resources proved inadequate, additional equipment was rented or purchased outright. Most of the purchased capital goods will be available for use in future cleanup operations and in other public works projects. The theoretically correct measure of the cost of these goods must reflect their residual values for potential future uses.

Estimating residual values poses several problems. Although one can physically examine pumps and other equipment for signs of wear, and thereby estimate what fraction of the useful life has been expended, this residual physical life may have little relationship to the useful economic life remaining. This perhaps anomalous result arises from the fact that future economic life is in large part dictated by future needs for the equipment. If large oil spills occur only rarely in Brittany, the equipment may go virtually unused. On the other hand, should a number of major spills occur there in the near future, it would make those goods much more valuable. Thus, to estimate the economic value of the capital goods remaining after the cleanup, one must both estimate their physical condition and predict future needs for this equipment.

Reports received on the physical condition of the equipment after the spill indicated that most of the equipment was still highly serviceable.[10] Estimated residual economic values were almost identical to the original purchase prices. However, these estimates are contingent upon significant future use, something that cannot simply be assumed. That the Amoco Cadiz is the second largest tanker spill ever recorded suggests that spills of similar size will occur only infrequently in the future. However, some of the equipment, such as pumps, may be used in other public works projects. Assuming no future use for the equipment in combating oil spills or in other public works projects would imply a residual value of zero, which is clearly unrealistic. This is indicated by the fact that some unknown quantity of equipment and materials stockpiled from previous spills was used during the Amoco Cadiz cleanup, although the quantity and value are not known. To account for the residual value of equipment and materials purchased during the Amoco Cadiz cleanup, it was assumed that 25 or 50 percent of the original market value of the equipment and materials remained at the end of Plan Polmar. In other words, the true social costs were assumed to be between 50 and 75 percent of the original market cost for the category, Purchased Equipment and Supplies. By ignoring the value of usable equipment and supplies already available at the time of the Amoco Cadiz spill, costs of equipment and supplies are underestimated to some extent.

Value-Added Tax

A final issue concerns the treatment of the French value-added tax (VAT). The rate of the VAT varies by the type of good, e.g., 7.6 percent for necessities such as food, 17.6 percent for goods such as pumps, booms, and lodging in hotels, 33 percent (top rate) for automobiles and books. Although these taxes were actually paid by the various funding agencies, the VAT represents a transfer within the French economy. Economic theory dictates that such transfers be netted out of the social cost calculations because they do not represent resources actually used. Thus, all costs presented here are net of the VAT.

SOURCES AND QUALITIES OF DATA FOR ESTIMATING COSTS

The response of the French national government under Plan Polmar was supplemented by labor, capital, and administrative support provided by various regional and local governmental units in Brittany. This section discusses the various sources and qualities of the data that were obtained for estimating costs. Understanding the relevance and importance of the data requires understanding the various activities which were involved. Plan Polmar-Mer is discussed first, followed by discussion of the more extensive and complex Plan Polmar-Terre.

Plan Polmar-Mer

Plan Polmar-Mer operations were coordinated at a command center called Poste de Commandment Polmar-Mer (PC Polmar-Mer), located at the naval headquarters in Brest. The marine activities can be divided into four broad categories: monitoring the movement of spilled oil; treating the oil; operations on the stricken vessel; and transportation of wastes. Monitoring was done by observation from helicopters and ships. Two basic methods were used to treat the oil: pumping; and chemical treatment, e.g., with dispersants, sorbents, and sinking agents. Operations on the vessel included rescuing the crew, attempting to place temporary pumping equipment on it, and eventually bombing the wreck to release all the remaining oil. Finally, PC Polmar-Mer coordinated the ocean transportation of wastes collected onshore through Plan Polmar-Terre, to refineries in Brittany and Normandy. To carry out these operations, PC Polmar-Mer used goods and services obtained from both the public and private sectors.

Significant among the public sector services provided through Plan Polmar-Mer were the operations of French naval vessels at sea and on standby alert. Data on the total number of vessels used each day were provided by PC Polmar-Mer. Data on the number of hours of service per day for each ship at-sea, and the number of ships on standby, were obtained from the French Navy. On the basis of mean hourly costs, as estimated by the Navy for internal accounting purposes, total costs per day were calculated for each vessel participating in Plan Polmar-Mer, including those on standby. The mean hourly operating cost estimates were based on a formula using fixed and marginal vessel costs along with naval budget allocations for manpower and equipment. Although it is not known exactly how the Ministry of Defense estimated mean costs, the investigators were told by Navy officials that they included expenditures for manpower, including overtime, fuel consumption, maintenance, and equipment depreciation. For aircraft and helicopters engaged in rescue operations, monitoring, and the bombing of the ship, data were obtained from the Navy on total hours of flight time for each type of aircraft used. Total costs were then estimated in a similar way as was done for Navy vessels, using hourly rates provided by PC Polmar-Mer.

Officials of PC Polmar-Mer were authorized to purchase goods and services from private companies. Through PC Polmar-Mer, it was possible to examine copies of the actual invoices for these items. One such category of expenditures was for small fishing vessels used for cleaning up oil at sea and transporting waste materials. Contracts with vessel owners covered a fixed period, at pre-set prices. Additional, unanticipated expenditures, such as boat repairs and cleaning, were added to the original contract prices upon completion of the work. Private companies also provided heavy equipment and supplied land-based transportation services. Materials such as dispersants, sorbents, chalk, and detergents were purchased from a large number of suppliers. The bills for these services provided accurate expenditure records.

Data were not available to support an analysis of marginal costs per unit of output for the Polmar-Mer operations. As mentioned above, it was not possible to establish a measure of output for the at-sea operations. Furthermore, for many of the cost categories not enough detailed information was available to determine exactly when some of the activities took place.

Plan Polmar-Terre

Four French departments were involved in Plan Polmar-Terre operations: Finistere and Cotes-du-Nord, whose shores were affected by oil from the spill; and Ille-et-Vilaine and Manche, where preparations took place to combat the spill, but whose shores were never oiled. The Ministry of Environment reviewed expenditures for all of the shoreside cleanup activities paid for by Plan Polmar-Terre. However, certain expenditures fell outside of the Ministry of Environment's responsibility and were paid for by other ministries or by local administrations.[11] Examples of this include restoration work and overtime pay to municipal workers and some of the services of firemen and policemen.[12]

Many of the data on input and output quantities in Finistere and Cotes-du-Nord were obtained from copies of daily telex reports provided by Polmar-Terre to the prefects, to the Ministry of Interior, and to the Ministry of Environment. The telexes constituted a record of the manpower and equipment used, or available for use, and the daily outputs for the entire Plan Polmar-Terre operation. It can be assumed that most of these resources were rarely idle during work hours, because it was relatively easy to shift inputs to other areas or activities. For limited periods, however, some of the telexes did mention situations of temporary equipment surpluses.

Officially, Plan Polmar-Terre extended for 167 days in Finistere, and for 101 days in Cotes-du-Nord. However, the telex reports did not cover these entire periods. Data for the first few days of the effort were not reported, and some later inputs were inexplicably not recorded

at all. Furthermore, operations subsequent to Plan Polmar-Terre, such as environmental restoration, did not appear in the telexes. It has been possible to supplement most of the missing data with information received from the Documentation Center for Research and Experimentation on Accidental Pollution of Waters (Centre de Documentation des Recherches et d'Experimentations sur les Pollutions Accidentelles des Eaux, CEDRE) in Brest and from the prefectures in Finistere and Cotes-du-Nord.

Outputs in Finistere were estimated in terms of daily quantities of oil and contaminated solids collected and placed in interim storage. For Cotes-du-Nord, outputs were measured by the quantities of oily liquid and oily solid wastes transported from interim to final storage and processing. Thus in Finistere, the daily results could be considered to be dependent on the manpower and equipment used the same day, but in Cotes-du-Nord the daily results depended more upon capacity for interim storage and the interval since the storage units had last been emptied. For this and other reasons, it was not possible to perform an analysis of per unit output costs in Cotes-du-Nord.

The objective of the telexes was to assist the Polmar-Terre command centers and the ministries in planning their budgets and in providing necessary manpower and equipment where and when it was needed. In addition to the principal categories reported on a daily basis, a few unusual or costly inputs occasionally appeared, and other items should have been listed but were not. For example, a very large truck would appear once or twice in the reports, but booms were not referred to at all. Local DDE workers were not listed in the telex reports—even though many of them were working on the spill from its outset—until later in the cleanup period when DDE crews from departments outside the spill zone became involved. Consequently, adjustments and additions had to be made to the telex data. Moreover, data from the two departments were not aggregated into identical categories, and the definitions of the categories changed over time. To facilitate classification of the data for purposes of analysis, the most highly aggregated scheme appearing in the telex reports was used. Tables 2-1 and 2-2 indicate what data were available from the daily telex reports issued for Finistere and Cotes-du-Nord, respectively.

Financial data for Plan Polmar-Terre were provided by the financial directors of the prefectures. The directors prepared vouchers for each bill, which then had to be approved by the prefects before payment could be made by the departmental treasuries. Invoice verification and payment followed standard French public accounting procedures.

Bills for goods and services provided by the private sector were available at the prefectures. Expenditure categories included rented equipment, purchased equipment, supplies, and services such as repairs, lodging, and meals. From these bills it was possible to identify the nature of the goods and services provided, the number of units, and the costs. Furthermore, because there were long delays in the payment of some bills, interest charges were paid to the affected private companies and were included as a cost of the spill.

Public agencies such as the Departmental Direction of Equipment, fire departments, nonprofit public companies such as highway departments, and communes were asked to pay for the costs of their operations and then to submit bills to the Ministry of Environment for reimbursement. These expenditures included fuel, overtime payments to workers, and other services. In some cases, such costs were not paid for by Plan Polmar, so agen-

Table 2-1.—Data Contained in Daily Telex Reports for Finistere, Amoco Cadiz Oil Spill.

Daily number in spill zone and total days of operation or work listed

Portable pumps	Backhoe tractors
Dump trucks	Road levelers
Sanitation trucks	Cranes
Tank trucks	Mechanical shovels
Fire engines	Bulldozers
Heavy equipment transporters	DDE workers
Honey wagons	Military personnel
Farm tractors	Firemen
Front-end loaders	Volunteers

Daily quantities listed

- Mousse pumped, m^3
- Mixed oiled sand, seaweed, and detritus picked up, m^3
- Mixed oiled sand, seaweed, and detritus picked up in sacks, m^3
- Beach areas cleaned, m^2 of surface area
- Rocky areas cleaned, m^2 of surface area
- Marsh areas and mudflats cleaned, m^2 of surface area

Table 2-2.—Data Contained in Daily Telex Reports for Cotes-du-Nord, Amoco Cadiz Oil Spill.

Daily number in spill zone and total days of operation or work listed

Portable pumps	Sanitation trucks
Tank trucks with low pressure pumps	Honey wagons
Tank trucks with high pressure pumps	DDE workers
Sanitation trucks	Military personnel
Heavy equipment transporters	Local public works personnel
	Volunteers

Quantities reported intermittently

Oily waste removed by truck from spill zone, tons
Oily waste removed by rail from spill zone, tons
Oily waste removed by ship from spill zone, tons
Oily solid waste transported from spill zone to temporary storage, tons
Oily solid waste transported from spill zone to permanent storage, tons

cies and communes accepted the financial liability. Examples include salaries for firemen, the administrative costs to organize Plan Polmar-Terre, and some of the costs of the Army and police. However, it was reported that reimbursement was eventually received, from funds of various ministries. Data on ministerial expenses were obtained from the French Judicial Treasury Agency.[13] In some instances, gift money was used to pay for expenditures incurred by public and private parties who were not reimbursed through Plan Polmar.

Three other sources of data on cleanup expenditures should be noted. The French Assembly and the French Senate both commissioned reports in which cleanup expenditures were estimated. However, because neither of these reports covered the entire cleanup period, the incomplete figures in those reports have not been used in the present analysis. The third source consisted of cost summaries prepared by the financial directors of the four affected departments. These summaries were used to check some of the estimates presented in the next section.

ESTIMATES OF CLEANUP COSTS

In this section are presented an estimate of the social cost of each major cleanup activity and the corresponding estimate of the total cost of cleanup. A range is shown for any category for which it was not feasible to make a point estimate. All values are in 1978 francs and are rounded to the nearest million francs.

Table 2–3 shows estimated costs incurred under Plan Polmar-Mer, and Table 2–4 shows estimated costs incurred under Plan Polmar-Terre. The total cleanup cost incurred by France, estimated as 430–475 million 1978 francs, is the sum of the costs of the two components.

The estimate of total costs is probably a lower bound, for two reasons. One, for a few activities for which expenditures were known to have been made, it was impossible to obtain information on the magnitude of the expenditures. Two, although cleanup and restoration activities continued beyond 1978, as noted previously, few or no data were available on costs incurred in years subsequent to 1978. However, it is believed that the costs reported here represent at least 95 percent of the total cleanup costs actually incurred.

Tables 2–5, 2–6, and 2–7 show the allocation of Plan Polmar-Terre costs to the departments in which they were incurred. For the first three expenditure items in Table 2–4, i.e., Army, volunteer labor, and police, no data disaggregated by department were available. The allocation of these expenditures between Finistere and Cotes-du-Nord was based on the proportionate deployment of these personnel in the two departments. Thus, these tables should be interpreted only as approximations of the costs actually incurred in those departments.

The costs presented above accrued almost entirely to the national government of France. Although some of the initial costs for the cleanup work were incurred at the local level, it was anticipated at the time of the analysis—and hence assumed—that they have been completely reimbursed by the national government. To the extent that some of the outlays were not reimbursed, those costs are regional in nature, with the financial burden falling directly on the citizens of Brittany.

Cleanup costs borne by countries other than France differ from those borne by France only to the extent that foreign governments and private parties outside of France paid for a part of them. It is not known whether any private donations came from foreign sources or not. Several governments did, however, contribute equipment

Table 2-3.—Estimated Costs of Plan Polmar-Mer by Expenditure Category, Amoco Cadiz Oil Spill.

Cost Item	Amount 10^6 1978 FR	Source of Data and Comments
Rented private vessels	15	Invoices submitted to the French Navy.
Rented pumping equipment	6	Invoices submitted to the French Navy.
Planes and helicopters, private and military	5	Private sector invoices submitted to the Navy and the Navy's internal cost estimates for naval aircraft.
French Navy vessels	14	Navy estimates which include depreciation, fuel, supplies, and maintenance costs.
French Navy labor costs	9	Navy estimates based on total days of effort and actual wages and salaries.
Miscellaneous purchased equipment & supplies	1	Invoices and inventory records provided by the Navy for such items as clothing and office supplies. No residual value was assumed to remain in any of these items after the cleanup effort ended.
Repairs and maintenance of Navy vessels	4	Navy estimates.
Chemicals	11	Navy inventory records and invoices. Some invoices were not paid because of disputes over the amounts being charged. Disputed bills represented only a small fraction of the total value of all of the invoices and are not included here.
Transportation of Navy equipment and personnel	<0.5	Navy expenditure records.
TOTAL	65	

and manpower to France, including the United States, United Kingdom, Belgium, The Netherlands, Norway, and Germany. Except for the contributions from the United Kingdom and The Netherlands, monetary estimates were unavailable. Table 2–8 describes the nature of the effort made by each of these countries and indicates the costs that were incurred by Great Britain and The Netherlands. A portion of the cost for the United States experts is included in the estimates of the value of the research contribution by the United States described in Chapter 6. Because of the nature of the data, it was not possible to separate cleanup and research costs in the United States contribution. The costs borne by non-French entities probably were on the order of 15 million 1978 francs.

Therefore, total cleanup costs were estimated to be 445–490 million 1978 francs. Of this total about 97 percent was borne by France and about 3 percent by the rest of the world.

MARGINAL AND COST-EFFECTIVENESS ANALYSIS

This section extends the analysis of cleanup activities to consideration of the relative effectiveness of separate operations and of how relative effectiveness changed over time. Many of the difficulties of performing the marginal analysis have been mentioned previously. Not only were there serious errors and omissions in the daily telex data, but it was also impossible, in most instances, to identify which inputs were allocated to which activities for any given period. The telex reports were simply at too high a level of aggregation. Nonetheless, if improvements are to be made in the conduct of future cleanup operations, particularly in terms of setting priorities for the use of men and equipment, it is imperative that attempts be made to learn as much as possible from past experience. Only when relative cost and productivity are taken into account explicitly in devising cleanup strategies can one expect the desired level of cleanup to be accomplished for something approaching minimum cost.

Even a cursory look at the telex reports showed that productivity of many of the activities declined rapidly as the cleanup operation progressed. This decline in productivity can be attributed in part to the cumulative impact of removal. As the most severely affected and most accessible areas were cleaned, work crews directed their attentions to regions of lower priority, where hydrocarbon deposition was either not as great or where

Table 2-4.—Estimated Costs of Plan Polmar-Terre by Expenditure Category, Amoco Cadiz Oil Spill.

Cost Item	Amount 10^6 1978 FR	Source of Data and Comments
Army	97	French Judicial Treasury Agency (AJT). Includes all Army expenditures for salaries, per diem living expenses, transportation,and equipment and supplies. Costs are based on actual Ministry of Defense estimates as provided to the AJT. It is not known what rate, if any, was used by the Army to depreciate capital equipment.
Volunteer labor	8	Prefectures of Finistere and Cotes-du-Nord. The official French minimum wage at the time of the spill was used as an estimate of the opportunity cost of volunteer time. A labor opportunity cost of 88.6 FR per eight-hour day was assumed for the approximately 35 thousand person-days of volunteer effort. In addition to the labor costs, 5 million francs were estimated to have been expended for board, room, and transportation for the volunteer labor.
Police	4	Ministry of Interior budget figures for all expenses related to police effort, including salaries, food and lodging, equipment, supplies, and transportation.
Department of Finistere	166 - 197	See sources of data in Tables 2-5, 2-6, and 2-7. These costs represent expenditures actually incurred by the prefectures of the four affected departments.
Department of Cotes-du-Nord	87 - 99	
Department of Ille-et-Vilaine	1 - 2	
Department of Manche	1 - 2	
TOTAL	364 - 409	

access for heavy equipment was more difficult. It is logical to expect that output per unit of productive input would fall over time, given these circumstances. In addition, over time, natural forces mixed the oil with water and solid materials on shore. Evaporation and weathering made the oil more widely dispersed and much more difficult to remove. Thus, in part, the cleanup operation can be viewed as a race against nature as crews attempted to recover oil-contaminated materials while they could still be easily removed.

The pumping of liquid mousse along the coast during the initial phases of cleanup illustrates declining productivity per unit of input over time. Table 2–9 shows that during the first ten days of recorded activity in Finistere, the output of mousse pumped in cubic meters (m^3) fell very quickly from approximately 1.2 per man-day of effort on the first day to between 0.07 and 0.16 m^3 per man-day beginning on the fifth day.

Other things held constant, declining productivity can be used as an argument to mobilize resources quickly in response to a spill. As natural forces disperse the oily residues, output per unit of input falls steadily, implying successively higher costs over time for removing the same quantity of contaminated material. Of course, as the oil weathers and is dispersed, the need for cleaning may also diminish. In the case of the Amoco Cadiz oil spill, the French administration perceived a need to respond rapidly so that the normal way of life in Brittany could be restored as soon as possible and the natural and man-made environments could be made ready for the summer tourist season.

With respect to the cost effectiveness of alternative cleanup methods, CEDRE compiled some preliminary data on the average costs and outputs of alternative methods for accomplishing roughly identical tasks during the Amoco Cadiz cleanup operations. For example, in the early phases of cleanup both honey wagons and vacuum trucks were used to remove liquid residues from nearshore areas. Typically, vacuum trucks were restricted by their weight to roads and piers; they were too heavy to use on beaches. Honey wagons were more mobile and gave much better access to beaches and remote coastal areas.

Productivities of honey wagons and vacuum trucks are shown in Table 2–10. The data indicate that honey wagons were considerably less expensive than vacuum trucks in terms of cost per unit output of oily residues with average hydrocarbon content of 10 percent, even

though the average capacity of honey wagons was much smaller and they often were operated under more difficult conditions.

Similarly, it is possible to compare various means of removing bits of polluted sand, tar balls, and similar materials from beaches. CEDRE compared manual

Table 2–5.—Estimated Costs of Plan Polmar-Terre in the Departments of Finistere and Cotes-du-Nord by Expenditure Category, Amoco Cadiz Oil Spill.

Cost Item	Amount: Finistere (1978 FR x 10^6)	Amount: Cotes-du-Nord (1978 FR x 10^6)	Source of Data and Comments
Army	70	27	The French Judicial Treasury Agency. No official figures are available to support an apportionment of Army personnel costs between these two departments. Therefore, costs were allocated proportionately based on the percentage of total personnel used in each department, 72.6 percent in Finistere and 27.4 percent in Cotes-du-Nord.
Volunteer labor	5	3	Prefectures of Finistere and Cotes-du-Nord. The official French minimum wage at the time of the spill was used as an estimate of the opportunity cost of volunteer time. A labor opportunity cost of 88.6 FR per eight-hour day was assumed for the approximately 35 thousand person-days of volunteer effort. In addition to the labor costs, 5 million francs were estimated to have been expended for board, room, and transportation for the volunteer labor. This amount was allocated between the two departments in proportion to the numbers of volunteer labor in each department.
Police	3	1	The French Judicial Treasury Agency. Because data on police activities during Plan Polmar-Terre were not kept on a departmental basis, the costs were apportioned in the same manner as above for the Army. Costs include wages, transportation, and room and board.
Communes	1	1	Prefecture records. An additional but unknown, unreimbursed sum has been spent by communes in Finistere and Cotes-du-Nord on cleanup activities. Primarily because of pending lawsuits, no data were available on these expenditures. The indicated amount is an estimate.
Departmental Direction of Equipment employees	6	2	The French Judicial Treasury Agency and the DDE office in Brest. This figure represents total salaries plus living and transportation expenses paid by the national government for these workers.
Fire departments	2	2	Prefecture records. Costs include wages; supplies, e.g., clothing, fuel, hand tools, repairs to equipment; and travel expenses, e.g., food and lodging. Depreciation costs on capital equipment are not included.
Purchased equipment and supplies	62-93	24-36	Actual invoices submitted to the prefectures. This category comprises various services, equipment, and supplies purchased by the departments which are not included in any of the above categories, e.g., tools, clothing, office supplies, electricity, heavy equipment, and chemicals. (See text for an explanation of the range used for this cost category.)
Rented equipment	53	33	Actual invoices submitted to the prefectures. This category represents costs for all rental equipment including honey wagons, cars and trucks, pumps, and earth moving-equipment.
Waste transportation and final disposal	21	21	Prefecture records. Includes the cost of preparing the sites and burying the oily solid wastes in public landfills and the costs of refining the oily liquids. Transportation costs include charges for carrying liquid wastes to refineries in railroad tank cars and ships. Because only a combined figure for both Finistere and Cotes-du-Nord was available, an arbitrary allocation of 50 percent of the total costs was made to each department.

Table 2-5.—Estimated Costs of Plan Polmar-Terre in the Departments of Finistere and Cotes-du-Nord by Expenditure Category, Amoco Cadiz Oil Spill—Continued

Cost Item	Amount: Finistere (1978 FR x 10^6)	Amount: Cotes-du-Nord (1978 FR x 10^6)	Source of Data and Comments
Fuel	<0.5	<0.5	Actual invoices submitted by the vendors of fuel used in the department's own and rented equipment.
Equipment repairs	10	<0.5	Actual invoices for repairs and cleaning of the department's own and rented equipment following the spill.
Restoration and bird cleaning	11	3	Actual invoices and information supplied by the prefectures on gift funds, which were used to fund part of the restoration of the environment and the bird cleaning effort. Because some of the restoration work was accomplished on structures, including roads, and natural areas that were already in partial need of repair before the oil spill, it is difficult to know exactly what portions of these costs are directly related to the accident. However, it is believed that at least 75 percent of the costs is directly related to the Amoco Cadiz spill.
TOTAL	244 - 275	118 - 130	

Table 2-6.—Estimated Costs of Plan Polmar-Terre in the Department of Ille-et-Vilaine by Expenditure Category, Amoco Cadiz Oil Spill.

Cost Item	Amount 10^6 1978 FR	Source of Data and Comments
Purchases and rental of services and equipment	1	Prefecture records. Includes the cost of renting earth moving equipment and other vehicles used to remove sand from the beaches and to replace it after the danger of oiling had passed. Other equipment and laborers were put on standby for an undetermined time following the spill. No discount was applied for residual values remaining in the equipment after the spill, due to a lack of appropriate data.
Local commune expenditures	<1	Prefecture records. Includes costs incurred by several communes to: remove clean sand from the beaches and to replace it; move endangered oyster stocks to safe areas and to replace them in their original positions; and prepare booms for possible deployment should it become necessary to do so.
Department of lighthouses and buoys	<1	Prefecture records. Includes costs for this agency's manpower and equipment contributions to the department during contingency operations.
Department of Equipment employees	<1	The French Judicial Treasury Agency. The Department of Equipment supplied workers and equipment in assisting the department to prepare for possible cleanup operations.
Prefecture workers	<1	Prefecture records. This category represents the costs of supplying departmental labor for the contingency effort.
TOTAL	1 - 2	

Table 2-7.—Estimated Costs of Plan Polmar-Terre in the Department of Manche by Expenditure Category, Amoco Cadiz Oil Spill.

Cost Item	Amount 10^6 1978 FR	Source of Data and Comments
Purchase and rental of services and equipment	1	Prefecture records. Includes the cost of renting earth moving equipment and other vehicles used to remove sand from the beaches and to replace it after the danger of oiling had passed. Other equipment and laborers were put on standby for an undetermined time following the spill. No discount was applied for residual values remaining in the equipment after the spill, due to a lack of appropriate data.
Fire department	<0.5	The French Judicial Treasury Agency. This category represents the costs of labor, equipment, and miscellaneous supplies that were used in helping the department prepare to combat the spill.
Department of Equipment employees	<0.5	The French Judicial Treasury Agency. Department of Equipment supplied workers and equipment in assisting the department to prepare for possible cleanup operations.
TOTAL	1 - 2	

Table 2-8.—Contributions to the Amoco Cadiz Oil Spill Cleanup Operation by Non-French Countries.

Country	Description	Monetary Amount
United States	Advice on cleanup strategy; loan of portable pumps, which were never used, for offloading the stricken vessel	Unknown
United Kingdom	Several British ships operated off the coast of France spreading dispersants on the slicks	Approximately 2 million British pounds (14 million 1978 FR)
Belgium	A team of cleanup workers which helped set up booms; loan of pumping equipment	Unknown
Netherlands	Loan of a special purpose work boat and pumping equipment	Approximately 159 thousand Dutch guilders (0.3 million 1978 FR)
Norway	Three naval ships were put on standby but were never called into service	Unknown
Germany	An unknown number of firemen were sent to assist the French cleanup workers	Unknown

Source: Smets, Henri, Organisation for Economic Cooperation and Development, Paris, France, 1981 (personal communication)

Table 2–9.—Quantity of Mousse Pumped per Man-Day, Department of Finistere, Amoco Cadiz Oil Spill.

Day	Output, Quantity of Mousse Pumped (m^3)	Number of Men at Work	Output Pumped Per Man-Day (m^3)
1	2000	1631	1.23
2	2800	2136	1.31
3	1050	2175	0.48
4	955	3172	0.31
5	400	3022	0.13
6	350	3090	0.11
7	240	3511	0.07
8	500	3112	0.16
9	420	4013	0.10
10	300	4161	0.07

Source; Daily telex reports, Finistere

Table 2–10.—Cost Effectiveness of Honey Wagons and Vacuum Trucks for Pickup of Oily Material, Amoco Cadiz Oil Spill.

	Capacity of Unit (m^3)	Output (m^3/day)	Cost of Liquids Pumped (FR/m^3)
Honey wagon	3 - 5	20	50 - 100
Vacuum truck	6 - 20	20	150 - 175

Source: Pasquet, R., 1980: Effectiveness and Costs of Beach Cleanup Techniques and Waste Disposal, Centre de Documentation de Recherches et l'Experimentations sur les Pollutions Accidentelles des Eaux, Brest, France, 25 pp. (unpublished report).

pickup to mechanical pickup with front-end loaders and graders. On average, mechanical pickup resulted in waste material with a hydrocarbon content of no more than 1 or 2 percent oil. Manual methods were much more selective, with waste material picked up averaging 5 to 10 percent oil, but they are much slower than mechanical methods. The costs per cubic meter of picked up material are shown in Table 2–11. Considering only pickup costs, mechanical methods are about one-tenth as costly as the manual methods, per cubic meter of material picked up. However, in some places mechanical methods cannot always be applied, e.g., places not accessible to such equipment or areas too vulnerable in relation to environmental stress caused by the mechanical equipment itself. Further, as Table 2–11 shows, the oil content of the manually picked up material is about five times that of the material picked up by mechanical methods.

Whether or not mechanical methods are more cost effective than manual methods depends on the ultimate disposition of the material. If the picked-up material is simply to be disposed of permanently in landfills, and if the cost of transportation of the picked-up material is approximately the same for both methods of pickup, then mechanical methods are clearly more cost effective where they can be used. However, if the picked-up material is to be processed to recover oil, then the comparison must be made in terms of the respective total systems, i.e., from oily material on the ground through the recovered oil at the refinery and the disposition of residuals from the refining operation. Costs of processing the oily material to recover oil depend on the concentration of hydrocarbons in the input and on the nature of the non-hydrocarbon materials. Insufficiency of data with respect to transport costs and processing costs precluded making such a comparison.

Storage and transportation of oily residues can be achieved by various alternatives. Collected oily residues typically moved through a chain of storage sites before final land disposal or processing at a refinery. In the spill zone, cleanup crews established a series of small, preliminary storage facilities. These facilities consist-

Table 2-11.—Comparison of Manual and Mechanical Methods of Pickup of Oily Material from Beaches, Amoco Cadiz Oil Spill.

Technique	Collected Material (m^3/man-day)	Oil Content %	Cost for Collected Material (FR/m^3)
Manual			
bulk material	2	5 - 10	200
bagged material	1	5 - 10	375
Mechanical			
front-end loader	100 - 180	1 - 2	20 - 35
grader and loader	about 180	1 - 2	30

Source: Pasquet, R., 1980: Effectiveness and Costs of Beach Cleanup Techniques and Waste Disposal, Centre de Documentation de Recherches et l'Experimentations sur les Pollutions Accidentelles des Eaux, Brest, France, 25 pp. (unpublished report).

ed of above-ground, metal tanks and hastily dug trenches lined with plastic which could hold only a few days of accumulated residues. Plastic-lined trenches were less expensive than prefabricated tanks, i.e., 5 FR/m^3 of capacity versus 7 FR/m^3. However, leaks frequently occurred in the plastic linings, thereby requiring recollection of the oily residues and making the plastic-lined trenches less effective. Thus, first cost alone is not an adequate indicator of cost effectiveness.

It is theoretically possible to extend the analyses of relative costs and changes in productivity to other cleanup activities. However, the existing data were so imperfect that the results would probably not have been very accurate. Thus no additional analyses of that type were undertaken.

It has been illustrated that relative costs and productivity can vary significantly among different operations that attempt to accomplish roughly the same ends. In order to choose the most cost-effective cleanup strategy for any given spill, managers should have a clear understanding of relative costs and productivities and how they change over time. A more complete record of input quantities and costs and of the output per unit of input for each major cleanup activity is needed to accomplish that goal.

SUMMARY AND CONCLUSIONS

Total cleanup expenditures by France represent the largest single, measurable category of social costs resulting from the Amoco Cadiz oil spill. The cleanup operations were organized under a French interministerial response plan called Plan Polmar.

The pressing need of the spill response managers for adequate information on the availability of manpower and equipment and the relative productivity of various cleanup techniques necessitated the collection and publication of daily telex reports. These telexes were sent to spill response command headquarters directly from field operations in the spill zone and provided an excellent profile of the overall effort that was made. In addition, each prefecture in the affected area, and the many branches of the French central government that became involved, kept records on the quantities of men and equipment that were used and the costs that were incurred during the cleanup operations. These data permitted an economic analysis of the cleanup activities in order to (1) provide an estimate of the full social costs of the cleanup operations; and (2) compare the outputs and costs of alternative cleanup techniques.

Another objective was to investigate decisions concerning priorities and the optimum extent of cleanup. This objective depends heavily on an understanding of the benefits of cleanup on an incremental basis. Such information was not generated in this or any other study component.

It must be emphasized that this assessment of total cleanup expenditures was an economic, not an accounting exercise. That is, it measured the real economic costs of the resources that were devoted to emergency response, cleanup, and restoration. In this regard, several adjustments were made to expenditure data received from the French government. These adjustments were made so that the estimated costs would reflect more closely the actual social opportunity costs of the resources that were used. The adjustments were these:

- Value-added taxes were excluded because they represent a transfer and not a resource cost.
- Services of volunteers were priced to reflect their opportunity costs.

- Capital goods were depreciated to reflect likely future use, not simply the physical wear and tear accruing during the Amoco Cadiz cleanup operations.
- Military personnel and equipment were valued at what their services could command in civilian employment.

Even with these adjustments it was difficult to make point estimates of the economic costs of all elements of response, cleanup, and restoration. One of the most serious problems was missing data. During the early stages of the cleanup operation, prior to the beginning of daily telex reports, practically no information on inputs and outputs was recorded. Several activities were partially or totally unrecorded even after the telex reports began, including much of the effort made by local communes and several weeks of work by DDE personnel and policemen. After activities under Plan Polmar officially ended, expenditures by local communes and labor services of volunteers, primarily local residents, were largely unrecorded. In addition, some restoration work was reported to have been undertaken by the departments of Finistere and Cotes-du-Nord and by some of the affected communes. Cost records relating to this work were not available.

Data accuracy was also a problem because of the cost estimation procedures used by the military. Records from the Ministry of Defense were used, but the investigators were able to verify neither the actual expenditures nor the methods used for allocating costs to capital equipment. There was no evidence that records were falsified or poorly kept; nonetheless, one could not be certain that military accounting procedures conformed closely with economic theory.

In other situations, the cost estimates might have erred simply because assumptions of unknown validity had to be made. A good example of this problem was the assumption concerning future oil spills which underlies the computed depreciation of capital goods. A similar problem involved ignoring the value of equipment and materials on hand at the time of the spill and used in the cleanup effort. In addition, it was not possible to account for all of the cleanup assistance provided to France by other nations.

Finally, as noted previously, some restoration activities continued into 1979 and beyond. However, no data on the costs of these activities were available, although these costs are believed to be small in comparison to those incurred in 1978.

Total French cleanup costs, including emergency response and environmental restoration costs, were estimated at 430–475 1978 francs (approximately 103–114 million U.S. dollars). The estimate is likely to be a lower bound, for the reasons cited above, but the investigators are confident that at least 95 percent of the actual costs are included. The cleanup costs paid by France were 365–410 million francs (approximately 87–98 million U.S. dollars) for the land-based component, Plan Polmar-Terre, and about 65 million francs (approximately 16 million U.S. dollars) for the at-sea component, Plan Polmar-Mer. The estimated costs for Plan Polmar-Terre were allocated among the four affected departments as indicated in Table 2–12.

Expenses were also incurred by several foreign countries that assisted France during the cleanup operation. Available data indicated that the United Kingdom spent about 14 million 1978 francs (about 3 million U.S. dollars) and The Netherlands about 300 thousand 1978 francs (about 75 thousand U.S. dollars). Total expenditures by sources from outside France probably amounted to about 15 million francs. Thus, measurable world costs for cleanup amounted to 445–490 million 1978 francs, about 15 million francs more than French costs.

Following the analysis of total costs, an attempt was made to measure marginal costs and productivity. Such marginal analysis is the key to achieving desired levels of cleanup and restoration at least cost. Some general findings emerged. First, the productivity and relatively low cost of pumps would seem to support their extensive use during the early days of a spill when the oil is still fluid and easily retrievable by pumping. Second, the mechanical methods were about half as expensive as manual techniques when beaches were easily reached by heavy equipment. Only when rocks are present, or when tar balls are very widely dispersed, do manual means become more cost effective. However, caution should be used in drawing any general conclusions from

Table 2–12.—Estimated Costs of Plan Polmar-Terre, by Department, Amoco Cadiz Oil Spill.

	1978 FR (x 10^6)	1978 U.S. \$ (x 10^6)
Finistere	244-275	58-66
Cotes-du-Nord	118-130	28-31
Ille et Villaine	1-2	<1
Manche	1-2	<1
TOTAL	364-409	87-98

this result. A different combination of mechanical and manual techniques under different conditions could produce widely divergent results from those reported here.

The applicability of the marginal analysis was limited by several factors. These include the high levels of aggregation in reported data that precluded an accurate assessment of marginal productivities; the special geographical and weather conditions that prevailed along the Brittany coast at the time of the spill, which might not be present for spills in other areas; and the limited testing of some forms of equipment, such as skimmers, that have been reported to be highly productive under conditions for which they are designed.

It is sometimes tempting to use economic data collected ex-post to second guess or critique the efficiency of management decisions that were made during an event such as an oil spill cleanup operation. For example, an exception might be taken to the decision to place booms directly across all of the estuaries, where they were almost totally ineffective, rather than to use the limited supply of booms to deflect the oil from a few of the estuaries while the oil was still out at sea. Such a criticism cannot logically be pursued on purely economic grounds, however. Other factors besides economics were at work, such as political considerations and the limited experience of the cleanup managers in dealing with a combination of adverse weather conditions and enormous quantities of spilled oil. With extensive prior training and planning, the cleanup crews might have been more productive. However, the costs of more extensive training and contingency planning might have outweighed any efficiency gains that could have been made. Moreover, it appeared that decisions on cleanup procedures were based largely on rational economic grounds. No evidence was found to suggest that the cleanup crews pursued needlessly expensive or unproductive methods to contain or clean up the spilled oil, and to restore the damaged environment. On the contrary, the results of the limited marginal analyses performed indicated that, over time, less costly or more productive techniques were substituted for ones that became less efficient due to the effects of cumulative removal, weathering, and dispersal of the oil through natural processes.

This analysis of cleanup costs has been instructive for a number of reasons. First, it laid out a workable methodology that should make it easier to conduct similar studies in the future. Second, the cost of cleaning up the Amoco Cadiz oil spill was found to be a substantial component of the overall costs of the spill. Third, additional data that would be necessary to conduct more thorough total cost and cost-effectiveness studies in the future have been identified.

NOTES

[1] All monetary values are for 1978 price levels. An exchange rate of 4.18 FR per U.S. dollar was used for all conversions.

[2] There have been several modifications to the original Plan Polmar. The most recent occurred in late 1978 after problems were encountered in implementing some of its provisions during the Amoco Cadiz cleanup operations. For example, the Army was not originally included as part of the response plan, but has now been made an integral part of it. For a detailed description of the present plan see Journal Officiel de la Republique Francaise, 1978.

[3] National Oil and Hazardous Substances Pollution Contingency Plan, 45 Code of Federal Regulations, 17832–17860, 19 March 1980. Some states also have similar oil spill contingency plans.

[4] Financial operations under Plan Polmar were coordinated by the French Ministry of Environment, which had primary responsibility for managing the national pollution emergency fund.

[5] The following reports contain additional descriptive information on the cleanup: Bellier and Massart (1979); Bellier (1979); Colin, et al. (1978); and Hann, et al., (1978).

[6] The question of how best to clean the estimated 300 thousand tons of oil-contaminated sediments in the Benoit and Wrac'h estuaries has been under study by the Centre de Documention des Recherches et d'Experimentation sur les Pollutions Accidentelles des Eaux of Brest. To date, no decision has been made on how to proceed.

[7] Interested readers are referred to the following reports and conference proceedings for additional information on the physical impacts of the spill: American Petroleum Institute (1979); Centre National pour l'Exploitation des Oceans (1978 and 1981); Hess (1978); and Union des Villes du Littoral Ouest Europeen (1979).

[8] A discussion of the distribution of costs is contained in Chapter 7.

[9] Short-run excess profits are defined as higher than normal profits occurring when the sale price for a good or service is higher than the long-run equilibrium price because of temporary excess demand.

[10] Pasquet, R., 1980: personal communication, Centre de Documentation des Recherches et d'Experimentation sur les Pollutions Accidentelles des Eaux, Brest, France.

[11] The official title of the French national pollution emergency fund is, Fonds d'Intervention contre les Pollutions Marines Accidentelles. Because in 1978 the fund did not contain enough revenue to cover all of the expenses of the Amoco Cadiz spill, individual ministry budgets were used to supplement it.

[12] The rules which govern Plan Polmar state that expenses incurred by any governmental body before the national government officially declares Plan Polmar in effect, or after it is declared over for a particular spill, will not be reimbursed by the French state. In Finistere, Plan Polmar-Terre went into effect on 16 March 1978 and ended on 31 August 1978; in Cotes-du-Nord it went into effect on 19 March 1978 and ended on 28 June 1978. It is not clear to what extent expenses incurred outside these periods were ultimately reimbursed by Plan Polmar.

[13] The French Judicial Treasury Agency (Agence Judiciaire du Tresor) of the Ministry of Economics and Finance is the agency formulating the damage claims of the French state against the entity(s) responsible for the spill.

REFERENCES

American Petroleum Institute, 1979: *1979 Oil Spill Conference Proceedings.* Washington, D.C., 640 pp.

Baudoin, H., 1978: *Rapport Commission d'Enquete Creee a la Suite du Naufrage d'un Navoire Petrolier sur les Cotes de Bretagne, le 16 Mars 1978.* Assemblee Nationale Report No. 665, Paris.

Bellier, P., 1979: *Lutte contre les Pollutions Marines Accidentelles par les Hydrocarbures—l'Experience de l'Amoco Cadiz.* Centre de Documentation des Recherches et d'Experimentations sur les Pollutions Accidentelles des Eaux, Brest, France, 193 pp.

Bellier, P., and G. Massart, 1979: The Amoco Cadiz oil spill cleanup operations—an overview of the organization, control, and evaluation of the cleanup techniques employed, in *1979 Oil Spill Conference Proceedings,* American Petroleum Institute, Washington, D. C., 141–146

Centre National pour l'Exploitation Des Oceans, 1978: *Amoco Cadiz: Premieres Observations sur la Pollution par les Hydrocarbures—Actes des Colloques.* Brest, France, 239 pp.

Centre National pour l'Exploitation Des Oceans, 1981: *Amoco Cadiz: Consequences d'une Pollution par les Hydrocarbures—Actes du Colloque International.* Brest, France, 881 pp.

Colin, A., J-M. Girault, M. Chauty, P. Noe, and P. Marzin, 1978: *La Catastrophe de l'Amoco Cadiz.* Commission d'Enquete du Senat, Journal Official du Senat, No. 468, Paris, 313 pp.

Gundlach, E., and M. Hayes, 1978: Investigations of beach processes, in Hess, editor, *The Amoco Cadiz Oil Spill—A Preliminary Scientific Report.* NOAA/EPA Special Report, National Oceanic and Atmospheric Administration, Boulder, Colorado, 85–196

Hann, R., L. Rice, M. Trujillo, and H. Young, 1978: Oil spill cleanup activities, in Hess, editor, *The Amoco Cadiz Oil Spill—A Preliminary Scientific Report.* NOAA/EPA Special Report, National Oceanic and Atmospheric Administration, Boulder, Colorado, 229–281

Hess, W.N., editor, 1978: *The Amoco Cadiz Oil Spill—A Preliminary Scientific Report.* NOAA/EPA Special Report, National Oceanic and Atmospheric Administration, Boulder, Colorado, 349 pp.

Organization for Economic Co-operation and Development (OECD), 1981: *Certain Financial Aspects of Prevention and Control of Oil Spills.* Report by the Environment Committee, Paris, France, 33 pp.

Union des Villes du Littoral Ouest-Europeen, 1979: *La Pollution Marine par les Hydrocarbures—Actes du Colloque,* Brest, France, 227 pp.

Chapter 3

MARINE RESOURCES

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INTRODUCTION

The economy of northern Brittany is based primarily on tourism, agriculture, and fisheries. The last is dominated by the production of aquacultured oysters. The open-seas fisheries are of marginal significance; only the harvesting of crabs and lobsters is economically important. The total marine harvest of Brittany amounts to only about 4 percent of the value of the marine harvest of France.

The categories of social costs discussed and evaluated in this chapter are losses of existing stocks and of expected outputs in oyster culturing, other aquaculture operations, shell fisheries, and open-seas fisheries; damages to seaweed harvesting and processing operations; damages to marine sand and gravel operations; damages to, and losses in value of, marine-related real property; damages to noncommercial marine biomass; and damages to sea birds. Virtually all of the estimated social costs to marine resources were incurred by the three categories of oyster-culturing, shell fisheries, and open-seas fisheries. For neither noncommercial marine biomass nor sea birds was it possible to make a monetary estimate of social costs. These two categories are discussed in Appendix A to this chapter.

Framework for Estimating Social Costs to Marine Resources

The social costs to marine resources as a result of the Amoco Cadiz oil spill are defined as the present value (1978 FR) of the time stream of reductions in real income for France and the rest of the world which resulted from the spill, for each of the categories indicated above. In accord with Chapter 1, the framework for estimating social costs is

$$SC = R + D - A - FC - CS - PS \quad (3\text{–}1)$$

where

SC = total social costs;
R = the market value of lost outputs, including losses expected in the future;
D = the cost of repairing or replacing damaged real or personal property plus loss of rental yields;
A = the alternative earnings of factors of production, e.g., workers, boats, farm equipment, which would have been used to produce the lost outputs;
FC = forgone costs of fuel and/or other real costs which would have been necessary to produce the lost outputs, but were not incurred;
CS = net change in consumers' surplus resulting from the oil spill; and
PS = net change in producers' surplus resulting from the oil spill.

Because of the limitations in economic and biological data, the methods used for estimating the social costs to marine resources were necessarily simplified. With respect to category R, the convention was used of measuring losses within the fisheries sector in *ex vessel* or dock prices, this being the market level at which the losses occurred. Given the high degree of competition in fisheries within the European Common Market and the easy availability of substitute supplies of fish products in wholesale and retail markets in France, the slight reduction in supplies of fish products resulting from the Amoco Cadiz oil spill would have been little noticed. This argument is supported by the fact that the oil spill region produced less than 1 percent of the finfish catch for France in 1976, 2 years before the oil spill, and produced only 4 percent of the overall marine harvest in the same year. Thus, it is reasonable to assume that neither the supplies of fish products nor the levels of wholesale or retail prices in France were affected by the spill.

The majority of the losses suffered in category D is represented by outlays and efforts for cleanup and restoration undertaken by the French government, as discussed in Chapter 2. Only a few specific industries, including oyster culturing and the wholesaling of lobsters, suffered significant damages to real or personal property which were not included in the cleanup effort.

Category *A*, alternative earnings of displaced workers, is not of great significance in the case of the Amoco Cadiz oil spill because the period of enforced idleness was short, except for the oyster producers, and because alternative employment opportunities open to displaced workers in the relevant part of Brittany at the particular time of year during which the spill occurred were almost nonexistent.[1] The government employed very few fishermen and other displaced workers in the cleanup effort. Those made unemployed by the incident had virtually no opportunities for monetarily renumerative activities in the short run. By about two months after the spill, most fishermen had returned to their boats, and the level of fishing effort in 1978 was not significantly lower than normal, except in the quartier maritime of Paimpol. In general, full-time workers in the oyster-culturing industry were not laid off by the producers. Because of their specialized skills, they were "too valuable to lose," according to the owners. Part-time workers had few alternative employment opportunities. Thus, the extent to which losses in these industries were offset by alternative gains elsewhere in the economy was limited.

A correct, consistent estimate of losses to the fishing industry must consider the possibility that certain costs of production might not have been incurred by the industry in the year of the spill. Such costs *would* have been incurred had 1978 been a normal year with respect to levels of fishing effort. This is the meaning of the term *FC* in equation (3–1). Savings in maintenance costs for fishing boats and other equipment would have been small in any case, because depreciation rates for fishing boats are almost independent of rates of use, especially over short periods. There were almost no savings in maintenance expenses in oyster culturing, because—as noted above—producers kept permanent employees on the payroll despite the interruption in production. Thus, the only potentially significant component of *FC* is reduction in fuel used by fishing boats. The estimate of this reduction is discussed in the subsequent section on open-seas fisheries.

Categories *CS* and *PS*, i.e., consumers' surplus and producers' surplus, respectively, were estimated to be approximately offsetting in their effects, because the impact of the oil spill on prices of fishery products was small, and damages in all other categories were minimal to negligible.

The accuracies of the estimates of social costs for the various categories of marine resources are obviously limited by the available data. This is particularly true with respect to oyster-culturing, shellfish production, and open-seas fisheries. The estimated losses are based upon what was known concerning these categories of fisheries at the end of 1980, including then current expectations concerning the rates of recovery of oyster production in the region. The long-run impacts of the Amoco Cadiz oil spill are not known at this time, and will remain unknown for some period of time, e.g., 5–10 years. Future evidence may show that the losses to these fisheries were underestimated because of the inability to predict these long-run impacts.

Concern for long-run damage was heightened when heavy spring storms in 1981 reentrained oil-laden sediments in the estuaries most heavily impacted by the oil spill, raising a new risk of damage to oyster-culturing in the region. Nevertheless, the hypothesis is that most of the damage to oyster production and open-sea fisheries has already occurred. Evidence from the Torrey Canyon and the Santa Barbara oil spills supports this belief (Mead and Sorensen, 1972). It should be emphasized that the analysis herein assumes no post-1979 damage to the fisheries of Brittany, with the exception of oyster culturing, and no attempt has been made to estimate long-run damages to the marine environment. Therefore, the estimate of social costs is biased downward, representing what probably is a *lower* bound.

Brittany Fisheries

The administrative structure under which the fisheries of Brittany are managed has its roots prior to the French Revolution and remains today a complex mixture of tradition and statutory law. Fisheries regulations and policy are carried out under both a formal administrative structure within the French government and a professional structure under the control of the fishermen and producers.

The formal administrative structure of fisheries management in France begins at the level of the Merchant Marine (Marine Machande), which operates five regional divisions. Each of the regional divisions is further subdivided into quartiers maritimes, three of which—Brest, Morlaix, and Paimpol—are located in the area affected by the oil spill. The quartiers maritimes are responsible for supervising the activities of numerous "stations" or ports. For example, the quartier maritime of Brest has supervision over ten stations, seven of which were affected by the oil spill. All four stations of the quartier maritime of Morlaix were affected by the oil spill; two of the four stations within the quartier maritime of Paimpol were affected.

In parallel with the administrative structure described above, there is a professional structure composed of the fishermen and the producers. These groups have greater power of management over the fisheries than is true for any similar group in the United States. At the top of this professional structure within France is the Central Marine Fisheries Committee (Comite Central des Peches Maritimes), under which—at the working level—there are local committees made up of boat owners and crew members. These local committees enforce any decisions made by representatives of the workers and owners involved in any single fishery, for example, the Interprofessional Committee of Oyster Producers (Comite Interprofessionel de la Conchyliculture), which represents the interests of those involved in oyster production.

Except in the case of cultured oysters, the fisheries of Brittany are mainly of the artisanal type in which most fishing effort is carried out by individual boat owners manning small, open boats, moving in and out of ports along the coast with the tides and always fishing within sight of land. The majority of the participants do not work for wages, but instead either own their own boats or work on the basis of a "share of the catch" formula. The boats are small by any comparison; most of them weigh less than 10 tons.[2] The share systems under which the catch is distributed vary among the different ports, but in general one share is awarded to the boat captain (or owner), one share to each crew member, and a separate share for the boat and—on the largest boats—for the engines and gear as well.

However, significant investments have been made in recent years in newer and larger fishing boats, in the oyster-culturing industry, in industries related to the holding of lobsters for marketing, and in the seaweed harvesting and processing industry. But the product of all marine-based activities is still small in relation to the total income of Brittany. It is perhaps true to say that the fisheries play their most important role as part of the culture of Brittany, wedded as it is to the legend that every Breton child was "born of the sea."

For the quartier maritime of Brest, the types of gear used in the various fisheries, the species caught, the seasons fished in 1978, and the distribution of fishing effort in terms of number of boats and number of fishermen in 1978 and 1979, are presented in Table 3–1.

THE OYSTER-CULTURING INDUSTRY

Only a small fraction of the oysters produced in Brittany come from natural oyster beds; most are produced in artificial or enhanced environments, using modern methods of oyster breeding and culturing. Oyster culturing began over a century ago in Brittany when the natural harvest of oysters began declining at a rapid rate (Amiand, 1979). Areas contiguous to bays and estuaries in France are part of the public domain; oyster producers lease these lands from the government on a long-term basis, usually 25 years. Significant investments are then made in the building of concrete impoundments (oyster parks) and other facilities, all of which become the property of the government when the leasing period ends.

Oyster culturing is complicated and painstaking. The first phase, termed "captage," usually occurs in the Bay of Morbihan in southern Brittany. Here collectors

Table 3–1.—Characteristics of the Fisheries Industry, Quartier Maritime of Brest, 1978 and 1979.

Gear Used	Species	Season in 1978	Number of Boats		Number of Fishermen	
			1978	1979	1978	1979
Nets	Plaice, sole, sea perch	All year	unknown		unknown	
Hand line or trawl line	Pollock, conger eel	All year	155	154	226	193
Traps	Crab, edible crab, spiny lobster, crayfish, lobster	All year	155	166	342	301
Oyster dredge	Flat oyster, creuse oyster	All year	17	17	49	48
Nets	Striped mullet Mackerel	Feb. 1 to May 15 March 1 to Oct. 31	68	73	97	104
Traps	Crab, edible crab[a]	March 15 to Oct. 15	14	30	21	63
Dredge	Scallop, whelk, clam, sea urchin, periwinkle	Jan. 1 to March 18 and Oct. 17 to Dec. 30	104	89	205	171
Cutting gear	Fucus Ascophyllum	March 1 to Dec. 30 March 15 to Nov. 30	52	33	52	33
Tearing gear	Laminaria	April 15 to Dec. 31	37	47	49	57
Hand picking	Carragheenan	June 1 to Sept. 30	89	80	101	90

[a] In the Bay of Brest.

Source: Monographie des Peches Maritimes, Marine Marchande, Direction des Affaires Maritimes, Brest, 1978 and 1979

are placed in waters near the breeding sites, to which collectors the larvae eventually fix themselves. Later the baby oysters, "naissain," are moved to the Bay of Morlaix where they are allowed to grow to an age of about 18 months. At this point, most oysters are moved to the Bay of Brest or elsewhere on the north coast of Brittany, where they are allowed to grow another year or more.[3] These oysters may then be finished or "refined" in fresher waters, such as the estuaries Benoit and Wrac'h, where they attain the desired color and flavor.

Oysters must be harvested and marketed at exactly the proper time; if they are allowed to mature too fully, the flesh will lose its tenderness and flavor and the oysters will have no value in the market. One of the causes of the heavy losses suffered by the oyster producers of Brittany as a result of the Amoco Cadiz oil spill was the fact that oysters which were moved from the area affected by the spill could not be returned to the estuaries or to the Bay of Morlaix in time to permit proper development before marketing. Of most significance, however, was the fact that the oyster parks in the affected areas could not be sown with new stocks while the oil contamination remained.

Two major species of oysters are grown in Brittany: the flat oyster, *Ostrea edulis*, which is the premier oyster of France, and the creuse oyster, *Crassostrea gigas*, a larger and more disease-resistant species. The latter was introduced in the region after a parasitic epidemic nearly destroyed the flat oyster culture of Brittany in the early 1970s.

The value of oysters produced in the three quartiers maritimes affected by the oil spill is indicated in Table 3–2, for 1975 through 1979. The large increase in the value of oyster production in 1979 shown in Table 3–2 was recorded in areas not affected by the oil spill, in particular the Bay of Brest.

In 1977, the quartiers maritimes of Brest and Morlaix together produced 926 metric tons of creuse oysters, 16.5 percent of French production, and 9,700 metric tons of flat oysters, 10 percent of French production. The production of oysters in these two quartiers maritimes, where the impact of the oil spill was heaviest, involved 470 individual producers or firms, leasing 1,155 hectares of semi-submerged oyster beds and 522 hectares of deep water beds. The oil spilled from the Amoco Cadiz did not reach all of these areas; in particular, the large areas of oyster beds in the Bay of Brest were not affected. Table 3–3 summarizes the situation of the oyster-culturing industry in the spring of 1978 in the areas affected by the oil spill.

Evaluation of the social costs of the Amoco Cadiz oil spill as it affected oyster producers was complicated by the fact that the major costs of cleanup of the oyster parks located in the estuaries were borne by the French government. Nevertheless, some of these costs were noted in documents as relating to individual enterprises. Furthermore, both government and private (from gifts) grants of compensation were made to oyster producers covering both true social costs and transfer costs such as interest payments due to banks on investments in oyster production. In arriving at final estimates of social costs, the cost data supplied by French government agencies and the Interprofessional Committee of Oyster Producers had to be adjusted (1) to eliminate costs included in the cleanup effort undertaken by the French government and included as cleanup costs in Chapter 2; (2) to avoid double counting, e.g., with respect to the costs of unemployment compensation paid to workers in the oyster-culturing firms, these costs having been implicitly included in the social costs estimated in terms of the value of the loss of oyster stocks and oyster production; and (3) to eliminate private (or transfer) costs, including payments by the oyster producers (partly from private gifts) of the taxes due on their lease concessions or the interest due on loans for their oyster parks.

Table 3–2.—Value of Oyster Production in the Quartiers Maritimes of Brest, Morlaix, and Paimpol, 1975–1979

	Value of production (FR x 10^6)		
Year	Flat Oysters	Creuse Oysters	Total
1975	54.4	14.9	69.3
1976	28.8	31.0	59.8
1977	18.6	33.4	52.0
1978	14.2	9.9	24.9
1979	52.2	28.9	81.1

Source: Affaires Maritimes, Depouillement des Statistiques Mensuelles d'Apports, 1980

Table 3–3.—Characteristics of the Oyster-Culturing Industry in 1978 in the Areas Affected by the Amoco Cadiz Oil Spill.

	Estuaries	Bay of Morlaix
Area in oyster culture, hectares	80	712
Number of firms	8	44
Annual production, 1977, metric tons	2,000	9,000
Oyster stock, April 1978		
Flat oysters, metric tons	200	155
Creuse oysters, metric tons	1,000	6,720
Employment, 1977		
Permanent	60-70	130
Seasonal	About 100	540

Source: D. Amiand (1979)

The estimate of future losses of oyster production was made on the basis of the known recovery of the stocks through 1980; the assumption—shared by many biologists in France—that the long-run recovery of the oysters is not seriously in question; and the belief that the image of Brittany's oysters will not suffer any lasting damage which would impair their future value in the markets of Paris and elsewhere. After much discussion of these issues with owners of oyster-culturing firms, government specialists, and representatives of the Interprofessional Committee of Oyster Producers,[4] it was concluded that oyster production would reach normal levels in the Bay of Morlaix in the 1981 season and in the estuaries in the 1982 season.[5]

The social costs to the oyster-culturing industry of Brittany comprise five categories:

1. Value of the stocks of oysters destroyed at the time of the oil spill, amounting to about 1,240 metric tons in the estuaries and about 5,160 metric tons in the Bay of Morlaix.

   These stocks are valued at their whoesale prices at the time of destruction. The value of about 50 metric tons of mussels destroyed in the estuaries is included in this cost category;
2. Costs of transferring oysters from polluted to non-polluted areas such as the Bay of Brest, the Bay of St. Brieuc, and southern Brittany, and then returning them to the Bay of Morlaix or to the estuaries after the cleanup.

   These costs are calculated on the basis of distance in kilometers of transportation required for each transfer. In total, 200 metric tons of oysters were transferred from the estuaries; 1,300 tons were transferred from the Bay of Morlaix;
3. Costs of cleanup of personal property, equipment, and buildings of the oyster-culturing firms beyond that carried out by the government in its cleanup efforts.

   This category of costs includes *extraordinary* costs only, i.e., costs beyond those which would normally have occurred in the production cycle;
4. Costs of cleanup and restoration of the lands leased by the oyster producers, beyond the level of cleanup of these lands provided by the French government;
5. Value of the loss of expected production of oysters over the years 1978–81, *net* of the loss of stocks accounted for in category #1 above.

The fifth category requires explication. The losses in production were based on the differences between *expected* levels of production, i.e., those achieved before the spill as reflected in Table 3–3, and the actual and predicted levels of production over the assumed period required to reach pre-spill levels. Pre-spill levels of production were assumed to be reached in the Bay of Morlaix in 1981 and in the estuaries in 1982. Table 3–4 shows the results of these assumptions in terms of estimated losses in production over the relevant time period.

Two assumptions were made in valuing these losses in production. First, the proportions of total production represented by flat oysters and creuse oysters would remain the same over time, at 10 percent and 90 percent, respectively. Second, the unit values were taken as the wholesale prices for these species known to be reasonable in 1978, namely, 15 francs per kilogram for flat oysters and 4 francs per kilogram for creuse oysters. On the basis of these assumptions and the estimated losses in physical production shown in Table 3–4, and using a real discount rate of 3 percent, the value of lost production was estimated.

Table 3–4.—Actual and Estimated Losses in Production of Cultured Oysters as a Result of the Amoco Cadiz Oil Spill.

Year	Bay of Morlaix				Estuaries				Net Loss, Bay of Morlaix Plus Estuaries, (metric tons x 10^3)
	Production (metric tons x 10^3)				Production (metric tons x 10^3)				
	Expected	Actual or Predicted	Gross Loss	Net Loss	Expected	Actual or Predicted	Gross Loss	Net Loss	
1977	9.0	9.0	0	0	2.0	2.0	0	0	0
1978	9.0	1.0	8.0	2.84[a]	2.0	0	2.0	0.76[b]	3.6
1979	9.0	6.5	2.5	2.5	2.0	0	2.0	2.0	4.5
1980	9.0	7.5	1.5	1.5	2.0	0.5	1.5	1.5	3.0
1981	9.0	9.0p	0p	0p	2.0	1.0p	1.0p	1.0p	1.0p
1982	9.0	9.0p	0p	0p	2.0	2.0p	0p	0p	0p
Total net loss (metric tons x 10^3)				6.84	Total net loss (metric tons x 10^3)			5.26	12.1

[a] Net loss = gross loss - loss of stocks in 1978 of 5,160 metric tons, accounted for in cost category #1.
[b] Net loss = gross loss - loss of stocks in 1978 of 1,240 metric tons, accounted for in cost category #1.

p = predicted.

The estimates of losses for the five categories listed above were based on cost data submitted to the French government by the committee of oyster producers and by stock data from individual producers and other experts. The estimated losses are shown in Table 3–5. The total cost estimate of 107 million 1978 francs is conservative for three reasons. One, no losses were assumed beyond 1981. Two, losses of production were evaluated at wholesale prices, thus assuming no losses at retail market levels. Three, no allowance was made for possible rising trends in production which might have occurred in 1979–81 in the two loss areas.

SEAWEED HARVESTING AND PROCESSING OPERATIONS

The marine areas affected by the Amoco Cadiz oil spill produce about 75 percent of the commercial seaweed harvested in France.[6] Seaweed harvesting has been transformed in recent years from a cottage industry providing employment to off-season fishermen and their families into a modern, capital-intensive industry dominated by large kelp-cutting boats costing as much as 700 thousand francs and capable of harvesting 2,500 tons of wet seaweed per year (Coat, 1979).

The decreasing trend from 1971 through 1979 in the total number of licensed boats used in seaweed harvesting in the affected areas is shown in Table 3–6. However, the effective harvesting capacity has actually increased, because the newest mechanized boats have many times the capacity of the small boats used in the early 1970s.

Data on the aggregate commercial seaweed harvest in the three areas affected by the oil spill are shown in Table 3–7. As indicated, the harvest of seaweed in these areas rose rapidly after 1971, reaching the highest levels in Brest and in Morlaix in 1978 and in Paimpol in 1979.

Several types of seaweed are harvested in these areas. The largest quantity consists of brown seaweeds, *Laminaria* and *Fucus,* which are used in the production of alginic acid or are converted into farina which is used for cattle feed. Some red seaweeds, mainly *Chondrus* and *Gigartina,* are also harvested in northern Brittany, using old-fashioned hand-cutting methods. After drying, these red seaweeds are converted into carragheenan. Many industrial goods, drugs, and food products use alginates or carragheenan in their production. Despite the fact that three-fourths of the seaweed harvested in France comes from the oil spill area, the gross value of the seaweed harvest in these areas is small, amounting to only about 6 million francs in 1979, as shown in Table 3–7.

After being harvested—and, for some producers, dried on the dunes—the seaweed is sold to one of six processing companies with factories located in northern Brittany. These factories employ about 600 persons. Thus, had they been shut down because of the oil spill, a significant social cost for the region and for France would have been incurred. However, managers of these factories pointed out that the world market in dried seaweed was in excess supply in 1978, and they were able to receive needed supplies of seaweed from many sources other than those affected by the oil spill. Paradoxically, the problem for these factories in 1978 was not a short-

Table 3-5.—Estimated Social Costs to the Oyster-Culturing Industry.

Category[a]	Social Cost (1978 FR x 10^6)
1. Wholesale value of oyster and mussel stocks destroyed, or unmarketable after transfer	37.0
2. Costs of transferring oysters out of the polluted zone, and returning oysters after cleanup	1.2
3. Costs of cleanup and restoration of buildings, oyster parks, equipment of oyster producers, above the level of cleanup provided by the French government	5.3
4. Costs of cleanup and restoration of the lands leased by the oyster producers, beyond the level of cleanup provided by the government	3.5
5. Value of loss of expected production of oysters over the years 1978-81, net of value of stocks accounted for in Category #1[b]	59.7
TOTAL COSTS	106.7

[a] Costs in first four categories were incurred only in 1978.

[b] The loss of expected production is valued without subtracting costs such as labor and equipment required for this production, because the oyster producers maintained most of their work force throughout the period of reduced output and continued expenditures required to maintain their stocks, equipment, and premises. Further, those employees who were temporarily laid off were unable to find alternative employment during their period of enforced idleness and thus produced no offsetting social income or product. The value of their leisure time might be considered an offset to the losses in oyster production, but the psychological costs of unemployment are assumed to have equaled or exceeded any benefits gained from leisure.

Table 3-6.—Number of Licensed Seaweed Harvesting Boats in the Amoco Cadiz Oil Spill Area, 1971-1979.

Year	1971	1972	1973	1974	1975	1976	1977	1978	1979
By quartier maritime of registry									
Brest	172	185	167	159	131	123	111	87	80
Morlaix	30*	30	32	43	33	25	26	26	24
Paimpol	20*	22*	24*	24*	26*	25*	23*	23*	22*
By type of boat									
Mechanized	15	22	30	39	41	42	49	55	70
Non-mechanized	207	215	192	187	149	131	111	81	56
TOTAL BOATS	222	237	223	226	190	173	160	136	126

*Estimated

Sources: Monographie des Peches Maritimes, quartiers maritimes of Brest, Morlaix, and Paimpol, 1971-1979; and Coat (1979).

Table 3–7.—Weight and Value of Seaweed Harvest in Areas Affected by the Amoco Cadiz Oil Spill.

Quartier Maritime	1971	1977	1978	1979
Brest				
Harvest Weight[a]	10.2	16.1	27.7	24.1
Value[b]	3.2	2.7	4.3	4.4
Morlaix				
Harvest Weight	2.2	4.1	6.8	3.7
Value	n.a.	1.1	1.4	0.8
Paimpol				
Harvest Weight	1.5	5.3	5.5	5.9
Value	n.a.	0.7	0.8	0.9
TOTAL (Brest + Morlaix + Paimpol)				
Harvest Weight	13.9	25.5	40.0	33.7
Value	n.a.	4.5	6.5	6.1

[a] metric tons x 10^3
[b] 1978 FR x 10^6

n.a. = not available

Source: Monographies des Peches Maritimes, 1971-1979 editions, all quartiers maritimes.

age of seaweed but a large surplus, produced because the factories had posted a high buying price in expectation that the oil spill would cut off their supplies. In fact, 1978 produced so large a seaweed harvest that the factories were forced to impose a quota on the 1979 harvest, reducing the allowable harvest of each boat by 21 percent below theoretical capacity. This quota, and not any residual effects of the oil spill, caused a reduction in the seaweed harvest in Brest and Morlaix in 1979 below the levels that were recorded in 1978, as shown in Table 3–7.

The large increase in the seaweed harvest in the year of the oil spill and the fact that this increase was most pronounced in the quartier maritime of Brest—the area hardest hit by oil pollution—would appear to render untenable any suggestion that the oil spill damaged the seaweed harvest. Nevertheless, it was argued by the producers that the 1978 seaweed harvest was lower than it should have been. Three factors were adduced in explaining the large size of the 1978 harvest despite the occurrence of the oil spill: (1) six new mechanized boats entered the industry; (2) the factories bought a larger proportion of the seaweed harvested in wet rather than in dry form; and (3) the harvest was pushed into areas farther from the coast, such as the Ile de Sein and Ile Molene.

With respect to the first contention, it must be noted that the number of mechanized boats has increased steadily since 1971, and that the entry of the six new mechanized boats in 1978 was partially offset by the departure of thirty nonmechanized boats, as shown in Table 3–6. Thus, the growth of potential harvesting effort in 1978 was not extraordinary or out-of-line with what had been observed in years prior to the year of the spill.

With respect to the question of the increased harvest of seaweed in wet form in 1978, it is true that this change in proportions of wet and dry harvested tends to exaggerate the size of the harvest in 1978. However, applying the accepted ratio for converting wet seaweed to dry seaweed of 5 tons wet = 1 ton dry, to the portion of the 1978 harvest reported as being wet, results in a total 1978 harvest of about 32.3 metric tons equivalent dry seaweed. This quantity is still about a fourth larger than the recorded 1977 harvest.

Finally, the decision to harvest seaweed in areas farther from ports than the usual harvest sites may be partly explained as a natural expansion of the harvest which would have occurred with or without the oil spill. The larger boats being introduced into the industry have their basic rationale in the fact that they are capable of harvesting for longer periods of time and farther from ports. The amount harvested in these new areas in 1978 was about 600 metric tons, or less than 2 percent of the reported 1978 harvest.[7]

The conclusion that the seaweed harvesting and processing industries of Brittany suffered no significant social costs as a result of the oil spill is supported by biological studies which show a limited impact of the oil upon the various commercial seaweed species (Topinka and Tucker, 1979). Seaweeds have a natural

barrier of protection in the form of a slick exterior coating. Further, crude oil may reduce the population of predators which graze on seaweed. As in the case of the Santa Barbara oil spill, which occurred in a similar seaweed harvesting area, no apparently significant short-run or long-run damage to the seaweed resource was caused by the Amoco Cadiz oil spill.[8]

In summary, both the harvest records and the biological evidence lead to the conclusion that the social cost of the Amoco Cadiz oil spill to the seaweed harvesting and processing industries was minor. The harvest was slightly delayed, some disruptions in the normal marketing arrangements may have occurred, and some areas not previously used as harvesting sites were employed in the harvest that year. There is no reason to believe that the oil spill will have any long-run effects on seaweed harvesting in Brittany. The market disruptions and the dislocation of harvesting effort noted above obviously imposed some social costs on France. Rather than ignore these costs, a nominal value of 50 thousand 1978 francs has been ascribed to them.

HOLDING TANK OPERATIONS (VIVIERS) FOR SHELLFISH

Enterprises involving holding tank operations for shellfish, which include some of the largest of their type in the world, buy shellfish—mainly lobsters—from fishermen and then hold them in tanks for live delivery throughout the year to restaurant and retail buyers. Buyers are located in all parts of the world. Because a single lobster sold for about 50 francs in 1978, the potential for damage to this industry because of the oil spill was serious. After the oil spill, some of the inventory of shellfish in the holding tanks was transferred out of the oiled zone, but the majority of the stocks was too fragile to survive transfer to other areas and was therefore lost.

Several firms in this industry were affected by the oil spill, primarily Primel, located in Plougasnou, and Societe Langouste, located in Roscoff. Damages to these firms included contamination of tanks, seawalls, and grounds; mortality to stocks; costs of transporting stocks to other areas; costs of replacing polluted water in holding tanks with clean water brought in from outside the area; loss of expected income because of reduced levels of sales in 1978–79; and costs of increased advertising and promotional activities which were made necessary by the change in the world-market image of the shellfish of Brittany.

The estimate of the social costs of the oil spill to the viviers is based upon data supplied by the firms involved. It is recognized that some of these data may not be completely objective. However, adjustments were made only to eliminate double counting and to exclude private (transfer) costs which are not true social costs. Costs of overtime wages paid to employees who participated in the cleanup of premises or the transfer of shellfish stocks are included in social costs on the assumption that the rate of overtime wages is market-determined and represents the disutility associated with reduction in leisure time below the level allowed for in the normal work week. Extraordinary costs of advertising and promotion may not be a social cost from the point of view of the world, because these activities may involve rivalry with other nations who could occupy the market niche formerly filled by the French firms. From a national perspective, however, "product image" or "goodwill" is an intangible capital ssset which produces real income for France. Erosion of this asset resulting from the oil spill represents a loss of real income to France; hence, an appropriate attempt to restore the value of this asset must be considered a legitimate social cost.

The estimated social costs to the two principal firms in the industry are shown in Table 3–8. Other smaller firms suffered limited mortality to stocks of crustaceans plus some restoration costs above the level of cleanup provided by the French government. The aggregate social costs for the smaller viviers were estimated to be about 200 thousand 1978 francs. Thus, the total social costs to the shellfish holding tank industry were estimated to be about 11 million 1978 francs.

EXPERIMENTAL MARINE AQUACULTURE

Small quantities of salmon (41 tons in 1977), sea trout (2 tons in 1977), and abalone are grown on an experimental basis in the oil spill area at Plouescat and St. Jean-du-Doigt. Most of the stocks of these species were transferred to other areas during the spill period. Some mortality occurred during and after the transfers. The total social costs of transportation and mortality to stocks were estimated to be less than 100 thousand 1978 francs.

OPEN-SEAS FISHERIES

The independence of the Brittany fishermen, and of the committees which represent their interests, has meant that statistics relating to fish catch and fishing effort in the region affected by the Amoco Cadiz oil spill have only recently been collected. It would have been desirable to have explained losses to open-seas fisheries using a model reflecting the underlying production relationships, that is, using catch and related effort data (Carlson, 1973). However, the available statistics did not provide enough information to permit a production function approach to be used successfully.

With respect to fish catch, the data which were available include records of fish catch, both weight and *ex*

Table 3–8.—Estimated Social Costs to Two Principal Firms in the Shellfish Holding Tank Industry.

Firm and Category of Cost	Cost (1978 FR x 10^6)	
S.A. Primel		
Destruction of shellfish stocks	0.28	
Transfer of stocks	0.09	
Restoring stocks to tanks	0.10	
Additional cleaning of premises	0.09	
Total costs for S.A. Primel		0.56
Societe Langouste		
Rebuilding tanks and cleaning premises	3.20	
Transfer of stocks	0.74	
Replacing seawater in tanks	0.28	
Loss of prospective income	3.80	
Extraordinary advertising and promotion	2.16	
Total costs for Societe Langouste		10.18
Total for the two firms		10.74

vessel, by month and by port (or station) for about 150 species of fish and shellfish for the period January 1971 through December 1979. The data relating to fishing effort were more limited and came from different sources. Annual reports are published which give the number of licensed fishermen and the number, weight, length, and horsepower of licensed fishing boats within each quartier maritime. No catch data are reported for individual boats. Fishing effort—as opposed to the capacity of the fishing fleet—could be measured only by the quantity of fuel used by each boat in each quarter for the period April 1974 through December 1979, i.e., 23 quarters. Data on fuel use were obtained from records of fuel tax refunds made to individual boat owners.[9] Because these fuel tax refund records are coded to the registration number of the boats involved, and registration records show the size, type, and horsepower of the boats, it was possible to construct a time series showing the total fuel consumption in each quarter for each *type* of boat within each port, and also the total and average horsepower of the boats.

These time series data are illustrated for the quartier maritime of Brest in Table 3–9, Figure 3–1, and Figure 3–2. Table 3–9 shows catch weight, real value of catch, fuel used by fishing boats, number of fishing boats used, average horsepower, and aggregate effective horsepower of boats which fished. The data cover the period from the second quarter of 1974 through the fourth quarter of 1979. Figure 3–1 and Figure 3–2 show the data graphically in terms of index numbers, with the first observation in each time series—that for the second quarter of 1974 (1974.2)—being the base = 100 for each index. Catch weight, real value of catch, and fuel used by fishing boats are plotted in Figure 3–1; number of fishing boats used, average horsepower of boats, and aggregate effective horsepower of boats in Figure 3–2.

There are serious problems involved in attempting to use the limited data on catch and effort to estimate a production function, or functions, for these fisheries. The central problem has been noted earlier, namely, catch data are not recorded by individual boat. Given that situation, for analysis one might group boats together by type of boat or by gear specifications, and then assume that all catches of certain species were made by a particular group of boats.[10] Such an approach is not valid in the case of the artisanal fisheries of Brittany because boats specialized for use in fishing for certain species, e.g., crabs and lobsters, are capable of being, and indeed are, used to fish for many other species during any given year.[11]

Table 3-9.—Fisheries Catch and Fishing Effort for the Quartier Maritime of Brest, Second Quarter of 1974 through 1979.[a]

Year	Quarter	Catch Weight (metric tons)	Real Value of Catch[b] (FR x 10^6)	Fuel Used by Fishing Boats (liters x 10^3)	Number of Fishing Boats Used	Horsepower (HP) of Boats	
						Average HP	Aggregate Effective (HP x 10^3)
1974	2	493	2.97	128	101	67	6.8
1974	3	506	2.85	183	138	68	9.3
1974	4	575	3.49	175	122	74	9.0
1975	1	312	2.30	115	53	78	4.1
1975	2	692	4.50	180	46	75	3.4
1975	3	766	5.75	383	76	84	6.4
1975	4	805	5.84	358	167	65	10.9
1976	1	452	3.32	168	89	63	5.6
1976	2	677	4.60	300	109	61	6.6
1976	3	538	4.03	340	105	60	6.3
1976	4	787	7.42	275	102	67	6.8
1977	1	566	3.81	171	80	70	5.6
1977	2	838	5.06	236	92	63	5.8
1977	3	755	5.03	473	128	51	6.5
1977	4	686	5.08	276	99	58	5.7
1978	1	383	2.76	159	80	70	5.6
1978	2	411	2.62	287	94	59	5.6
1978	3	488	3.55	454	116	57	6.6
1978	4	620	4.38	271	92	60	5.6
1979	1	362	1.97	236	86	64	5.5
1979	2	645	3.51	368	111	58	6.5
1979	3	542	3.24	514	145	56	8.1
1979	4	1154	7.34	326	76	61	4.6

[a] The data are for the seven of the ten stations (ports) in the Quartier Maritime of Brest affected by the oil spill: Le Conquet, Portsall, Aber Wrac'h, Plouguerneau, Kerlouan, Molene, and Ouessant.

[b] Real value of catch was obtained by modifying the nominal value by the consumer price index for France.

Sources: Fisheries catch data from Office of Administration, Quartier Maritime of Brest; effort data from records of claims for fuel tax refunds and from boat registration records.

What could be constructed from the available data is a production function for these fisheries which describes the relationship between *aggregate* fish catch and *aggregate* fuel use, or horsepower, or boat tonnage, for each port. The limited number of observations on the variables involved—fifteen prior to the oil spill, eight during and after the oil spill—together with the fact that catch would be defined as the aggregate of all species lumped together, greatly impairs the utility of this type of production function in forecasting losses to these fisheries. Therefore, the analysis of losses to open-seas fisheries was made using a modified, trend-extrapolation, forecasting model rather than a production function approach.

Before applying this model, a test was made for the significance of any changes in the level of fishing effort in the period following the oil spill in order to correct for savings in social costs which would have occurred if a decline in fish catch were associated with a decline in effort. The model employed for this test used fuel consumption within each quartier maritime—or, alternatively, the aggregate horsepower of the fishing boats which were used in each quartier maritime—as a proxy for fishing effort.[12] The model is

$$E_q = a + bY + \sum_{i=1}^{3} c_i S_i + dD + u_t \qquad (3\text{-}2)$$

where

- E_q = fishing effort in each quartier maritime, measured in liters of fuel used by fishing boats or in aggregate effective horsepower of the fishing boats used in any quarter;
- a = intercept;
- b, c_i, d = coefficients to be estimated;
- Y = an annual trend variable, with 1974=1;
- S_i = seasonal (quarterly) dummy variables;
- D = a dummy variable representing the division of the time series into observations prior to the oil spill, for which $D=0$, and observations during and after the oil spill, for which $D=1$; and
- u_t = a randomly distributed error term.

This model may be interpreted as follows. If the variable D is shown to be significant in any of the regres-

sion equations, it may be presumed that a significant change has occurred in the seasonally-adjusted trend level of effort in that region. Therefore, some adjustment may be necessary in the estimate of net social costs.

Two results were obtained from the regression analyses. One, for the equations which used fuel consumption within each quartier maritime as a proxy for fishing effort, the variable *D* was negative but statistically insignificant for Brest and for Morlaix; it was negative and statistically significant for Paimpol. Two, for the equations which used aggregate effective horsepower as a proxy for fishing effort, the variable *D* was positive but statistically insignificant for Brest and Paimpol; it was positive and statistically significant for Morlaix. In summary, these results indicate that a statistically significant decline in fishing effort —in terms of fuel use—occurred in Paimpol after the oil spill and that a significant increase in fishing effort—in terms of aggregate effective horsepower—occurred in Morlaix. No significant change in fishing effort, measured by either of the two proxy variables, occurred in Brest in the post-oil-spill period. The implication of these findings for the estimates of net social costs of fishery losses in these quartier maritimes is discussed below.

The overall significance of the marine harvest, i.e., fisheries catch plus seaweed harvesting, in the three regions affected by the oil spill is shown in Table 3–10. As indicated, the total value of the marine harvest in the three quartiers maritimes together amounted to only 85 million francs in 1979. Thus, these fisheries are very small in comparison to others in France, representing about 4 percent of the value of the marine harvest and less than 1 percent of the value of the finfish catch for France in 1976 (Bonnieux, et al., 1980).

The numbers of licensed fishermen and registered fishing boats in the three quartiers maritimes of Brest, Morlaix, and Paimpol over the period 1972–1979 are shown in Table 3–11. This table depicts the decline in the numbers of fishermen and fishing boats in these areas, particularly in Brest, which has occurred since 1972.

A Model for Estimating Social Costs to Open-Seas Fisheries

Theory Underlying the Model

The economic theory underlying the estimate of social costs of the oil spill to open-seas fisheries is illustrated in Figure 3–3. This figure gives a simple rep-

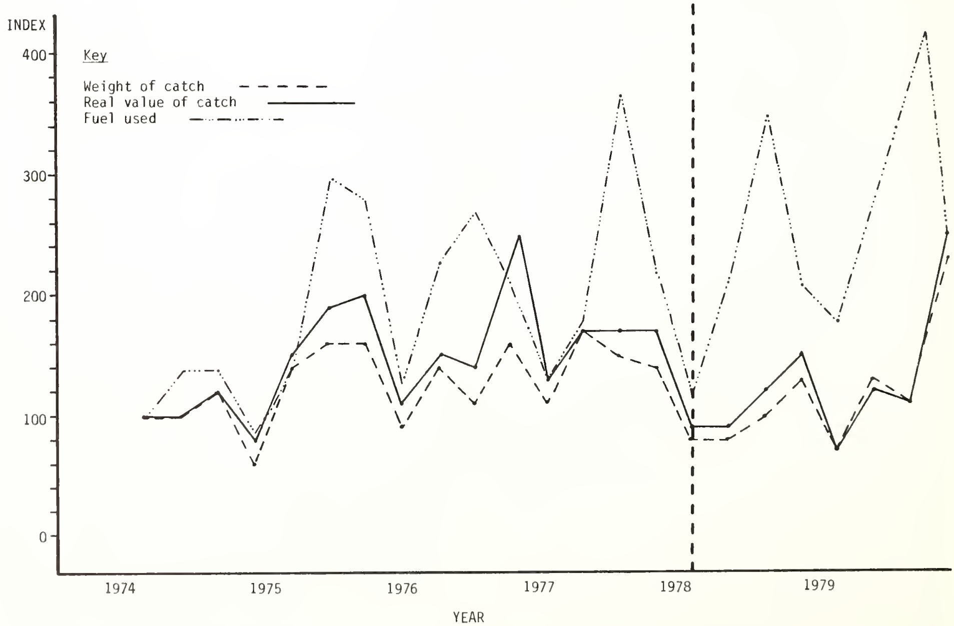

Figure 3-1.—Plots of Indices of Catch Weight, Real Value of Catch, and Fuel Used by Fishing Boats, Quartier Maritime of Brest, Second Quarter of 1974 through 1979.

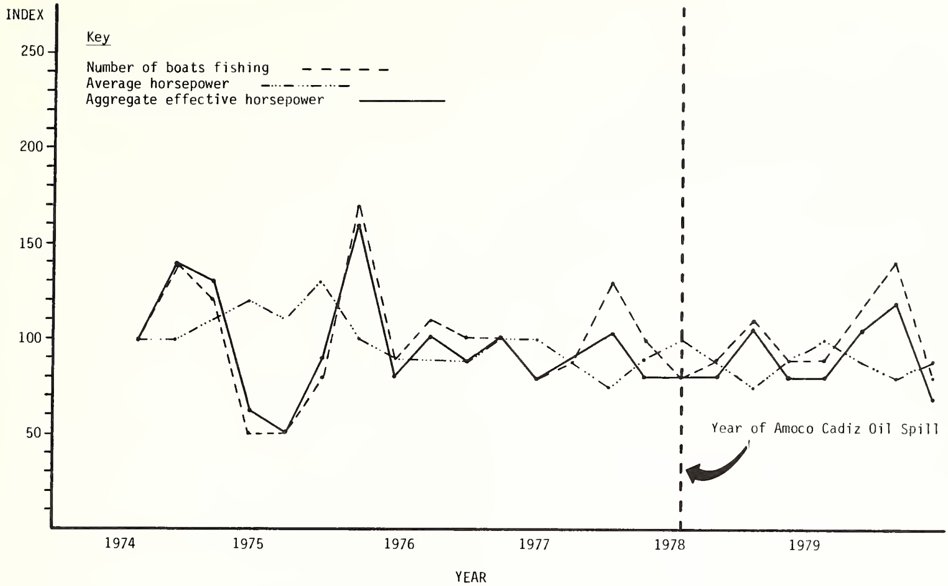

Figure 3-2.—Plots of Indices of Number of Fishing Boats Used, Average Horsepower of Boats, and Aggregate Effective Horsepower of Boats, Quartier Maritime of Brest, Second Quarter of 1974 through 1979.

Table 3-10.—Total Value of Marine Harvest in Quartiers Maritimes of Brest, Morlaix, and Paimpol, 1977–79.[a]

	Value of harvest (FR x 10^6)		
Quartier Maritime	1977	1978	1979
Brest	28.0	26.8	33.4
Morlaix	31.3	27.2	33.1
Paimpol	15.3	12.4	18.3
TOTAL	74.6	66.4	84.8

a Excluding cultured oysters.

Source: Monographies des Peches Maritimes, 1977-79

resentation of the losses of real outputs and of the changes in the levels of consumers' and producers' surplus resulting from the Amoco Cadiz oil spill. Because the resources, i.e., labor and capital, employed in these fisheries are extremely immobile in the short run, the supply curves of effort—S_1 and S_2—are assumed to be nearly vertical, i.e., virtually inelastic, within a given season. In the absence of the oil spill, the total catch in these fisheries would have been Q_1, yielding an *ex vessel* price of P_1. The oil spill had only a small effect on the level of the overall effort within these fisheries in 1978 and 1979 but, instead, reduced the *productivity* of each unit of effort, moving the supply curve to the left, i.e., to S_2. The real price of the catch—that is, the market price in the absence of any inflationary increase—rose slightly from P_1 to P_2.

Table 3-11.—Numbers of Licensed Fishermen and Registered Fishing Boats, Quartiers Maritimes of Brest, Morlaix, and Paimpol, 1972–1979.

Quartier Maritime		1972	1976	1977	1978	1979
Brest	Fishermen	1001	859	807	725	685
	Boats	565	491	450	422	403
Morlaix	Fishermen	464	439	453	444	444
	Boats	252	209	214	214	212
Paimpol	Fishermen	474	464	472	474	462
	Boats	304	285	299	276	283

Source: Monographies des Peches Maritimes, 1972-1979

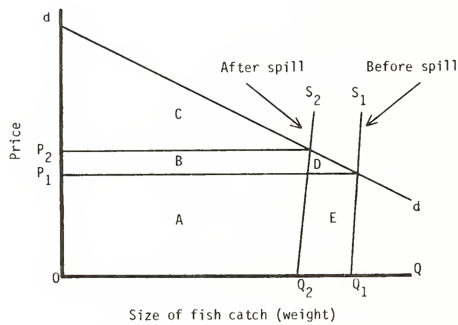

Figure 3-3.—Shift in Relationship Between Fish Catch and Price as a Result of Amoco Cadiz Oil Spill.

As discussed above, because of the nature of the available data, a modified, trend-extrapolation, forecasting model was chosen to estimate losses to fisheries in the three affected areas. This model captures the movement of outputs from Q_1 to Q_2 and values these losses at the levels of real prices *predicted* to have occurred in the absence of the oil spill. Area E in Figure 3–3 represents estimated losses. The higher real price actually observed after the oil spill, P_2, transferred some consumers' surplus to producers, as indicated by area B. This represents a private cost to consumers, and a private benefit to producers, but leaves overall social welfare unchanged. Area C represents the remaining consumers' surplus, after the change in prices.

Area D is the deadweight loss which occurs as a result of the price increase and is an element in social costs. It is ignored in the forecasting model because it is assumed to be very small, given the small decrease in total fish catch, Q_1-Q_2, and the even smaller increase in real price, P_2-P_1, because of the availability of substitute fish products from unaffected markets.

Form and Application of the Model

The data base used in the analysis consisted of the official French government records of monthly catch, value and weight, by species for each station affected by the oil spill over the period January 1971 through December 1979. These are the earliest and latest data on fisheries catch which were available at the time of the analysis. All data were obtained from hand-entered ledger records in the administrative offices of the quartiers maritimes of Brest, Morlaix, and Paimpol. Data from each of the affected stations within each of these three regions were aggregated to create a time series of monthly catch by quartier maritime. The individual species catch records were then combined into three groups reflecting biological and technical (catch method) similarities: (1) finfish, mainly pollock, macker-

el, bass, plaice, and mullet; (2) crustaceans, i.e., lobsters, crabs, and shrimp; (3) and mollusks, i.e., clams, mussels, periwinkles, and cockles, but specifically excluding aquacultured oysters and scallops (coquille).[13]

Because the French government administration had not compiled the data needed for the analysis on machine-readable cards or tapes, it was necessary to transfer the ledger records of fish catch onto Fortran sheets, then onto cards, and finally onto computer tapes. Some obvious errors and inconsistencies in the data, such as species prices greatly out of line with contemporaneous prices in other regions, were corrected in the process of creating the final data tapes.

The regression equations used for forecasting losses were of the following form:

$$C_{iq} = a + bY + \sum_{j=1}^{11} c_j M_j + u_t, \qquad (3\text{-}3)$$

where

C_{iq} = weight or real value of catch of the i^{th} species grouping within a given quartier maritime by month;
a = intercept;
b, c_j = coefficients to be estimated;
Y = an annual trend variable;
M_j = monthly seasonal adjustment dummy variables; and
u_t = a randomly distributed error term.

The initial analysis showed u_t not to be randomly distributed. The method by which correction for this autocorrelation problem was made is described in Appendix B to this chapter.

The statistical coefficients for the independent variables for each equation were first estimated using the time series of catch by month—defined either as the weight of catch or the real value of catch—for the period prior to the oil spill, i.e., for the period January 1971–February 1978. The estimated coefficients for each equation were then used to forecast the *expected catch* for each month following the oil spill, i.e., March 1978–December 1979. By comparing *actual* to *expected* catch, monthly estimates of the loss or gain in the months following the oil spill were derived. Table 3–12 illustrates the results, in terms of catch weight, for finfish for the quartier maritime of Brest.

Inspection of the results for each of the species groups for each quartier maritime shows that the net losses incurred in these fisheries are very much a function of the number of months which are included in the loss period. A reasonable scientific rule for selecting the loss period would be based upon some definitive biological study of fish stocks, with the loss period ending when the stocks had returned to normal. Because there do not appear to be any definitive biological studies of fish stocks for the region, the loss period had to be assigned on a more arbitrary basis. A loss period for each species group which maximizes the net loss recorded for that group is clearly inappropriate because, during a recovery period, some of the early losses of catch will very likely be recouped. Given the data which were available, covering 21 months following the oil spill, it may not be possible to select the true period of loss for some species groups if the losses for these groups extended beyond December 1979. Thus there was a necessary element of arbitrariness in the choice of a loss period. The decision was made to report fisheries losses for the period extending to the end of the data series, i.e., through December 1979.

Both the economic theory of the rational fishing firm and many practical studies of the behavior of fishermen indicate that the objective of the captain of a fishing boat is to maximize *revenue* rather than weight of catch in choosing a fishing strategy. For this reason, estimates of losses to open-seas fisheries were based on forecasting equations of the form of equation (3–3), using the real (1978) value of catch as the dependent variable.[14] The results using the forecasting equation for finfish for the quartier maritime of Brest, in terms of real value of catch, are shown in Figure 3–4 and Table 3–13.[15] Figure 3–4 provides a visual impression of the goodness of fit between recorded and predicted levels of catch value in the period prior to the oil spill. Predicted losses are shown for the post-oil-spill period beginning in March 1978. Months in which actual catches exceeded expected catches are represented by sections of the "predicted loss" curve below the x-axis, i.e., as negative losses [gains]. The figures in the "predicted loss" column of Table 3–13 which have a negative sign represent levels of actual catch *above* those forecasted for those months. It would be illogical to ignore these gains in catch when computing the net losses suffered by each fisheries group, because such gains—and an offsetting proportion of the losses—reflect the normal variance of catch around the seasonally adjusted trend values implicit in the forecasts of predicted catch values.

Table 3–14 shows the coefficients of determination (R^2) for the regressions on real value of catch for the three species groups and the three quartiers maritimes. Because six regression equations were estimated for each quartier maritime—for each of the three species groups and for two measures of catch, real value of catch and weight of catch—results for all eighteen regression equations are not included here.[16]

Cumulative losses [gains] for the three quartiers maritimes and the three species groups for the period March 1978–December 1979, are shown in Table 3–15. In deriving this table, the gains and losses for the months subsequent to March 1978, shown in Table 3–13, were discounted to their March 1978 values, using a real discount rate of 3 percent.

Table 3-12.—Recorded and Predicted Catch Weights, and Predicted Losses and Gains, for Finfish, Quartier Maritime of Brest, 1971-1979.

Year	Month	Recorded Catch Weight (metric tons)	Year	Month	Recorded Catch Weight (metric tons)	Year	Month	Recorded Catch Weight (metric tons)	Year	Month	Recorded Catch Weight (metric tons)	Predicted Catch Weight (metric tons)	Predicted Loss or Gain[a] (metric tons)
71	1	16.0	73	4	32.2	75	7	50.0	77	10	35.0		
71	2	14.4	73	5	30.7	75	8	47.0	77	11	25.1		
71	3	27.5	73	6	30.5	75	9	41.8	77	12	24.3		
71	4	29.1	73	7	35.9	75	10	41.5	78	1	29.1		
71	5	27.7	73	8	35.7	75	11	30.6	78	2	25.9		
71	6	34.8	73	9	29.1	75	12	26.4	78	3	10.7	44.9	34.2
71	7	33.8	73	10	32.1	76	1	25.2	78	4	12.5	49.1	36.6
71	8	38.6	73	11	28.1	76	2	41.7	78	5	25.1	46.2	21.1
71	9	30.0	73	12	23.1	76	3	42.8	78	6	36.4	51.5	15.1
71	10	26.3	74	1	8.8	76	4	45.5	78	7	47.0	55.9	8.9
71	11	26.1	74	2	16.3	76	5	48.2	78	8	52.5	56.2	3.7
71	12	18.8	74	3	25.4	76	6	57.3	78	9	43.2	54.5	11.3
72	1	7.5	74	4	24.7	76	7	47.7	78	10	49.3	46.2	-3.1
72	2	18.7	74	5	25.2	76	8	52.2	78	11	48.8	40.1	-8.7
72	3	20.0	74	6	28.5	76	9	85.5	78	12	24.8	36.9	12.1
72	4	30.2	74	7	34.7	76	10	42.3	79	1	45.1	32.9	-12.2
72	5	23.5	74	8	37.7	76	11	38.3	79	2	34.9	37.4	2.5
72	6	25.4	74	9	26.0	76	12	34.7	79	3	48.9	48.2	-0.7
72	7	35.7	74	10	27.2	77	1	29.2	79	4	47.6	52.4	4.8
72	8	32.5	74	11	24.0	77	2	29.9	79	5	57.0	49.4	-7.6
72	9	31.3	74	12	23.6	77	3	52.9	79	6	66.3	54.8	-11.5
72	10	28.3	75	1	15.5	77	4	49.5	79	7	62.2	58.7	3.5
72	11	18.0	75	2	22.1	77	5	46.7	79	8	73.7	59.4	-14.3
72	12	15.9	75	3	36.3	77	6	55.9	79	9	49.5	57.6	8.1
73	1	19.2	75	4	46.8	77	7	62.3	79	10	54.2	49.3	-4.9
73	2	16.5	75	5	35.6	77	8	61.5	79	11	49.6	43.3	-6.3
73	3	26.2	75	6	40.2	77	9	47.9	79	12	32.4	40.1	7.7

[a] Predicted loss or gain = predicted catch weight minus recorded catch weight; negative indicates gain.

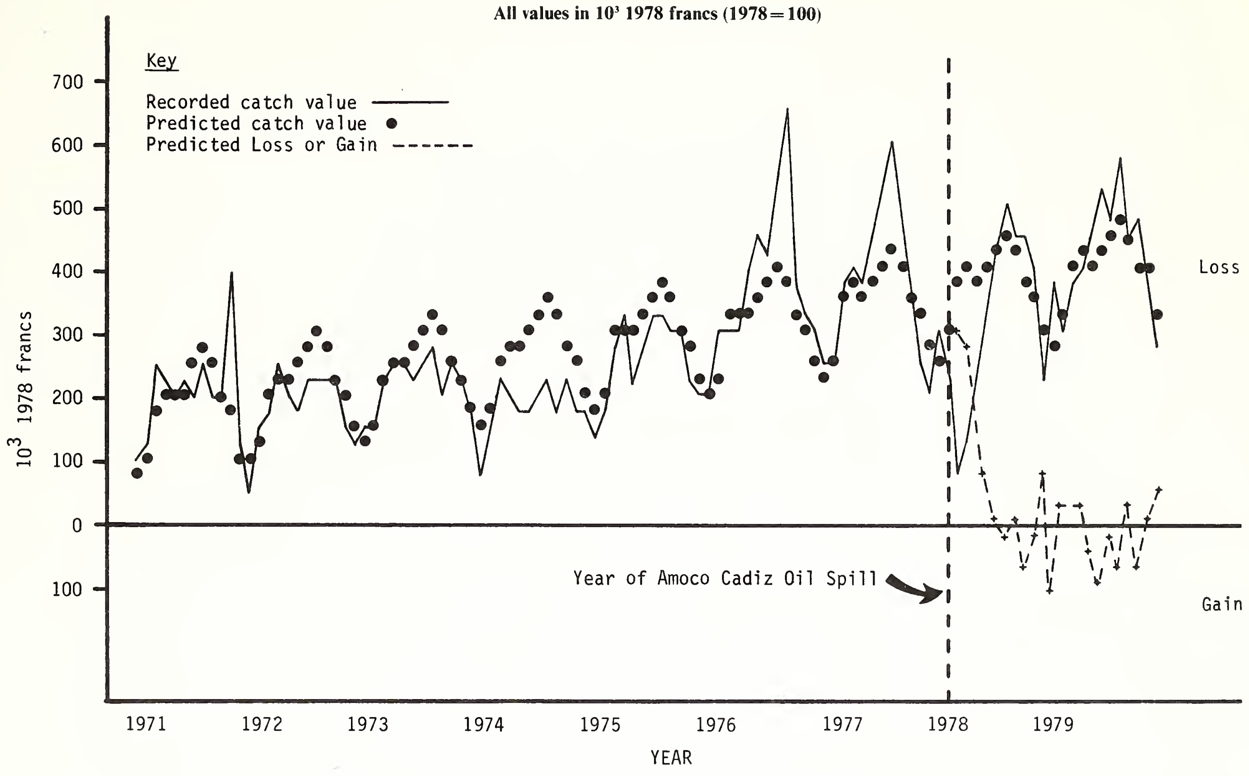

Figure 3-4.—Recorded and Predicted Catch Values, and Predicted Losses and Gains, for Finfish, Quartier Maritime of Brest, 1971–1979.

Table 3-13.—Recorded and Predicted Catch Values,[a] and Predicted Losses and Gains, for Finfish, Quartier Maritime of Brest, 1971-1979.

Year	Month	Recorded Catch Value (FR x 10^3)	Year	Month	Recorded Catch Value (FR x 10^3)	Year	Month	Recorded Catch Value (FR x 10^3)	Year	Month	Recorded Catch Value (FR x 10^3)	Predicted Catch Value (FR x 10^3)	Predicted Loss or Gain[b] (FR x 10^3)
71	1	106	73	4	245	75	7	325	77	10	341		
71	2	115	73	5	248	75	8	314	77	11	239		
71	3	242	73	6	231	75	9	288	77	12	209		
71	4	232	73	7	247	75	10	305	78	1	299		
71	5	193	73	8	267	75	11	228	78	2	227		
71	6	235	73	9	212	75	12	198	78	3	80	369	289
71	7	210	73	10	248	76	1	197	78	4	113	391	278
71	8	242	73	11	217	76	2	301	78	5	222	377	155
71	9	198	73	12	174	76	3	304	78	6	331	400	69
71	10	189	74	1	81	76	4	305	78	7	417	429	12
71	11	396	74	2	146	76	5	388	78	8	494	460	-34
71	12	135	74	3	214	76	6	442	78	9	444	434	-10
72	1	46	74	4	197	76	7	418	78	10	453	379	-74
72	2	149	74	5	170	76	8	548	78	11	391	363	-28
72	3	184	74	6	179	76	9	642	78	12	223	302	79
72	4	257	74	7	200	76	10	368	79	1	383	281	-102
72	5	192	74	8	226	76	11	329	79	2	299	316	17
72	6	178	74	9	182	76	12	302	79	3	369	396	27
72	7	232	74	10	215	77	1	248	79	4	394	418	24
72	8	220	74	11	183	77	2	249	79	5	443	405	-38
72	9	233	74	12	172	77	3	383	79	6	518	427	-91
72	10	213	75	1	128	77	4	388	79	7	482	457	-25
72	11	146	75	2	177	77	5	386	79	8	565	486	-79
72	12	120	75	3	278	77	6	440	79	9	440	460	20
73	1	155	75	4	322	77	7	532	79	10	472	407	-65
73	2	143	75	5	234	77	8	598	79	11	385	389	4
73	3	229	75	6	263	77	9	477	79	12	278	328	50

[a] Real value of catch, where 1978 value = 100.

[b] Predicted loss or gain = predicted value minus recorded catch value; negative indicates gain.

Table 3-14.—Coefficients of Determination for Regression on Real Value of Catch for Three Species Groups, Quartiers Maritimes of Brest, Morlaix, and Paimpol.

Quartier Maritime	Finfish	Crustaceans	Mollusks
Brest	0.40	0.67	0.35
Morlaix	0.39	0.75	0.50
Paimpol	0.69	0.78	0.33

The regression analyses of losses of real catch values in the three regions in the period after the oil spill, summarized in Table 3-15, showed that (1) a significant loss of catch for all species occurred in the quartier maritime of Brest; (2) a much smaller loss of catch for crustaceans and mollusks occurred in the quartier maritime of Paimpol than in the quartier maritime of Brest; (3) a significant increase in real catch value was recorded in the quartier maritime of Morlaix for two species groups, finfish and crustaceans.

One explanation for the estimated increase in real catch value recorded in Morlaix is the significant increase in effective horsepower of the fishing boats used in this quartier maritime in the period after the oil spill. Another factor may be that the fishing grounds used by the Morlaix boats were less affected by oil, because they are farther from shore. The most likely factor is that the increased catch resulted from the more intensive fishing effort undertaken by the Morlaix boats after their period of immobilization ended.

The estimated gain in real catch values for open-seas fisheries in Morlaix after the oil spill forces making an uncertain decision as to whether (a) to ignore these gains in catch of finfish and crustaceans in Morlaix in

Table 3-15.—Estimated Cumulative Losses (Gains) in Real Catch Value for Open-Seas Fisheries, Quartiers Maritimes of Brest, Morlaix, and Paimpol, March 1978–December 1979.[a]

Quartier Maritime	Finfish	Crustaceans	Mollusks	Total Loss
Brest	0.49	6.34	7.62	14.45
Morlaix	[1.61]	[5.90]	0.37	0.37[b]
Paimpol	0.94	0.33	0.45	1.72

[a] All values in 1978 FR x 10^6

[b] Gains in finfish and crustacean catches in Morlaix have not been offset against losses in mollusk catch because the three species categories are assumed to be relatively independent in terms of substitution of fishing effort.

estimating social costs; or (b) to deduct them from the losses recorded in the mollusks species group in Morlaix, or in the other areas. The correct decision is believed to be to ignore these gains. It is difficult to accept the hypothesis that the oil spill improved the fisheries in the quartier maritime of Morlaix, because evidence of migration of stocks is lacking. Substitution of fishing effort from the mollusk group to the other fishery groups in Morlaix was not believed to have been an important factor in this case, and movement of fishing boats from other areas into Morlaix was even less likely. Also, it should be noted that some increase in fishing effort occurred in this area in the post-oil-spill period. In summary, the gains recorded for two fisheries groups in Morlaix are believed to be independent of the losses incurred in the other fisheries group in Morlaix and independent of the losses suffered in other areas and, therefore, should not be deducted from those losses.

A small correction in the estimate of social costs of fishery losses in Paimpol must be made to account for the fact that a significant decline in fuel used by fishing boats occurred in 1978 in this region. It is assumed that fuel used in 1978 would normally have reached the plateau level of about 400 thousand liters recorded in 1977 and 1979. The amount of fuel actually used in 1978 was about 100 thousand liters less than would have been expected under normal conditions. The savings in social costs, net of government taxes, associated with this reduction in fuel use amounts to about 42 thousand francs, based upon a social cost of diesel fuel in the spring of 1978 in France of about $18.00 per barrel.

Adjustment for unreported fisheries catch. The accuracy of the estimate of losses to the open-seas fisheries of Brittany is very much dependent upon the accuracy of the value and weight data on fisheries catches reported by the French government. The method by which these data are obtained is not the same as that used in the most modern U.S. fisheries, where daily fish catches by boat are recorded on "fish tickets" which are machine readable. Rapid and accurate reports on both catch and effort can be obtained under the U.S. system. In Brittany, fish catches are estimated by a French government official who works in each port and who, through a combination of knowledge of the species caught and of the capability of the fishermen operating out of the port, can judge the size of each day's catch. Tests conducted in the U.S. have shown this method of estimating catch weight to be quite accurate. The prices paid to the fishermen are not always true "auction" prices, but it is difficult to know how adjustments might be made for the absence of a fully functioning competitive market. In summary, the official data on values of catch have been accepted and used in the analysis.

An important problem stems from the fact that a significant, but unknown, proportion of the fish catch in all areas of France is not officially reported. Part of this unreported catch is made by non-professionals—so-called "foot fishermen"—who are allowed to fish for their own consumption without any licenses. These fishermen account for perhaps 5 percent of the total catch in each quartier maritime. Another part of the unreported catch is diverted to beaches or coves outside the ports before the fishing boats return to port. This catch may then be sold to local restaurants or even to neighbors and friends or disposed of on a bartered basis.

No definitive analysis of the question of what proportion of the fish catch in Brittany goes unreported was made in this study. However, some who have studied the question believe the proportion to be quite high for some species.[17] Although underreporting is recognized as a problem, it is not considered serious by French government officials who work most closely with the fisheries or by the fishermen themselves and by their representatives in the Local Committee on Marine Fish-

eries in Brest. Therefore it is assumed that, on average for all species and all areas, the fraction of the fisheries catch in Brittany which goes unreported is about 20 percent.[18] This includes the catch of non-professional fishermen and of professional fishermen who do not land their full catches in the official ports.

Given the above assumption, then—if all catches were fully reported—both the expected levels of fish catch by species group in each area and the actual levels of catch reported would have been 20 percent higher. Thus, the loss estimates for each quartier maritime have been increased by 20 percent above the levels shown in Table 3–15 to obtain final estimates of social costs, in terms of 1978 values of production, to the open-seas fisheries of Brittany. These estimates, shown in Table 3–16, yield a total of about 20 million 1978 francs. Confidence intervals for these forecasted losses are not given for reasons having to do with the statistical properties of the forecasting models used.[19]

Damage to Fishing Boats and Equipment

A final category of social costs to the open-seas fisheries of Brittany comprised damage to fishing boats, motors, and gear. These damages were not included in the French government's cleanup effort and, thus, were not reported as part of the costs of that effort. To obtain an estimate of these costs, a mail survey of fishermen was undertaken in the summer and fall of 1980. Of the 100 fishermen selected at random to receive the survey form, 22 responded. The response rate was not low considering the length of the questionnaire, the fact that much specific information on costs and the nature of fishing operations was requested, and the desire for privacy on the part of the fishermen of Brittany.

While this survey cannot be considered scientifically valid either in its form or in its statistical properties, it is believed to give a reasonably accurate picture of the effect of the oil spill on these fishermen. It is clear that all the respondents were affected by the oil spill. Indeed, the average number of days following the spill before these fishermen returned to *regular* fishing activities was 59.

Most of the costs of cleanup of boats and equipment involved hours of work by the fishermen themselves during this period of enforced inactivity in fishing. The survey indicated that individual fishermen put in from 8 to 480 hours cleaning and repairing their boats. Because this was time which they otherwise would have spent in fishing and because no adjustment was made for the opportunity cost of this time in the estimates of fisheries losses, this time cost is assumed not to be an additional social cost.

Out-of-pocket costs of repair are another matter, however. These are clearly social costs. Based upon the average out-of-pocket expenditures of fishermen in the population sampled, the average fisherman operating a boat out of one of the ports affected by the oil was estimated to have incurred an extraordinary cost of cleanup and repair of his equipment amounting to about 3 thousand francs. These costs were probably not uniform among all ports and all quartiers maritimes, but the differences should not be very great, because the Amoco Cadiz oil found its way into all 13 ports for which damages in this category have been assigned.

Damages to fishing boats were assumed to have affected only those boats which actually fished out of the 13 affected ports in 1978, that is, 140 boats in the quartier maritime of Brest, 137 boats in the quartier maritime of Morlaix, and 94 boats in the quartier maritime of Paimpol. Assigning an average out-of-pocket cost of cleanup and restoration for these 371 fishing boats of 3 thousand francs, based on the survey described above, yields an estimate of the costs incurred by the open-seas fishing industry for damages to boats and equipment of about 1.1 million francs.

OTHER MARINE-RELATED SOCIAL COSTS

Marine Sand and Gravel Operations

Eighteen boats dredge for marine sand and gravel in areas offshore from Brest and Morlaix which were affected by the oil spill. The marine sand and gravel de-

Table 3–16.—Net Social Costs to the Open-Seas Fisheries of Brittany.[a]

Quartier	Finfish	Crustaceans	Mollusks	Total Loss
Brest	0.58	7.61	9.15	17.34
Morlaix	No loss	No loss	0.44	0.44
Paimpol	1.13	0.40	0.54	2.07
Less adjustment for reduced cost of fishing effort in Paimpol				-0.04
TOTAL NET COSTS				19.81

[a] All values in 1978 FR x 10^6

posits themselves were not affected by the oil, but dredging activities were suspended during the early period of cleanup. Assuming that this interruption of the dredging activities averaged 2 weeks for each boat, and caused 2 weeks of unemployment for 50 crew members, the total social costs to this industry were estimated to be about 0.1 million francs, based on average wage rates in the industry.

Damage to Real and Personal Property

This category includes damages to sea walls, buildings, equipment, and boats not included under other headings in this study and not included in governmental cleanup costs. Most of the damage included in this category was suffered by the health-related hotels and clinics located in Roscoff. The estimate of social costs in this category is based upon the record of compensation paid to these firms out of a governmentally administered fund, much of which was provided by gifts made to the region by the people of France and other countries. Because the compensation payments made out of this fund appeared to amount to about half the true losses suffered, the losses in this category were estimated to be about twice the known level of compensation, or about 0.75 million francs (Congar, 1981).

Changes in the Value of Real Property

Economists have recognized for some time that differences in the market values of residential properties located in areas of greater, as compared to areas of lesser, environmental amenities such as air quality and noise, may be used to infer the economic value of improvements in environmental amenities. Economic models which use differences in environmental amenities as one of the variables explaining differences in the market value of real properties require an elaborate and well-defined data base containing information on all demand-enhancing qualities of the houses or lands whose prices are used as observations in the models, such as number of rooms, heating and air conditioning equipment, distances from work and from shopping, indicators of neighborhood quality. Given a large enough number of observations on market prices and a specific enough definition of the relevant explanatory variables, including the variable defining ambient environmental quality, it may be possible to show a statistically significant relationship between the level of environmental quality and the market price of real property. But the data requirements and the conceptual difficulties of such studies are very great, even for areas where market information is both readily available and generally accurate.[20] This type of model cannot be used to analyze the effects of the Amoco Cadiz oil spill on the value of real property in the affected region because of the limited number of real property sales which take place in this area in any one year and the fragmentary information which is available concerning the properties themselves and the prices for which they have been sold.

Yet it is indisputably true that if the oil spill had the effect of depressing the value of real property either temporarily or permanently, a loss of explicit or implicit rental yields must have occurred, and this loss—computed in present value terms—should be added to the other social costs of the oil spill. Some attempt should, therefore, be made to give substance to the possible effects of the oil spill on real property values.

Given the severe limitations on available data relating to market prices of property sold in the oil spill region in periods before and after the oil spill, a simpler method of investigation of this question was adopted. Six real estate agency managers were interviewed in the city of Brest where most real estate transactions involving property in the region affected by the spill take place. Each manager was given a careful description of the purposes of the study and was asked for referrals to other more fully-informed persons within the firm if he had any serious doubts concerning answers to the question. The response of these six managers was uniformly that the oil spill had no discernible effect on prices paid for real estate in the affected region in 1978 and 1979.

Three general reasons were given by these managers for their unanimous conclusion that the oil spill had not affected real estate prices. One, the oil spill was a temporary, accidental phenomenon. No buyer would expect such accidents to occur on any regular basis. The price paid for real estate is based on the long-run outlook for the region. Two, if the oil spill had any effect on real estate prices, such an effect would be impossible to disentangle from the many other variables, mostly economic and relating to the general state of the French economy, which were at work. Three, there is very little property available for sale in the affected region in any one year. The people of Brittany tend to keep land within the family. Bretons who have lived most of their lives in other parts of Europe tend to return to Brittany when they retire. These and other potential buyers expressed no specific concern over the oil spill in describing the kinds of properties they would want to buy.

Of course, opinions of these real estate agents do not represent definitive proof of the absence of any effects on real estate prices. An oil spill of this magnitude should probably, on balance, have been a negative factor in the real estate market of the affected area. Nevertheless, there is no specific evidence upon which to base an estimate of positive social cost in this category. For this reason it has been concluded that the oil spill did not affect property values beyond the level of the direct forms of damage which were restored in the cleanup effort.

SUMMARY AND CONCLUSIONS: MARINE RESOURCES

The estimated social costs to marine resources are summarized in Table 3–17, in terms of 1978 present values. The estimate of about 140 million 1978 francs in

Table 3-17.—Summary of Costs to Marine Resources.

Category	Present Value of Costs (1978 FR x 10^6)
Oyster-culturing industry	107
Seaweed harvesting and processing industry	<0.1
Holding tank operations for shellfish	11
Salmon, sea trout, abalone experimental aquaculture operations	<0.1
Open-sea fisheries	20
Uncompensated damage to fishing boats and equipment	1
Marine sand and gravel operations	0.1
Damage to real and personal property	1
Changes in value of real property	Negligible
Noncommercial marine biomass	a
Sea birds	a
TOTAL (rounded)	140 (34)[b]

[a] No estimate of monetary cost possible.
[b] U.S. dollars x 10^6 at 4.18 francs per dollar.

social costs to marine resources makes the Amoco Cadiz oil spill the most costly spill recorded in terms of losses to fisheries and marine-related activities.

About three-fourths of the marine resources costs were incurred by the oyster-culturing industry; about 85 percent of marine resources costs were accounted for by oyster-culturing operators and viviers of shellfish, reflecting the importance of these fisheries and their special vulnerability to the oil spill. Open-sea fisheries accounted for about 14 percent of the marine resources costs of the spill. As stated in the beginning of the chapter, it was not possible to make credible estimates of monetary damages to noncommercial marine biomass and to sea birds.

There are a number of problems which make the estimation of fisheries losses difficult. Many of these problems will confront other investigators concerned with assessing damages to fisheries from future spills or environmental incidents, and it is important to reemphasize some of the problems mentioned previously.

One fundamental problem in estimating fisheries losses is the inability to measure long-term effects. Although losses to oyster culturing were projected to occur through 1981, it is not clear that this period of time adequately reflected possible longer-term losses. In some areas physical manifestations of the spill are still evident. For example, in the Wrac'h and Benoit estuaries, intensively used for oyster culturing at the time of the spill, the sediments in both were still heavily contaminated with hydrocarbons three years after the spill. Normal biodegradation works slowly because the contact of oxygen with the oil is limited. With respect to Ile Grande Marsh, in 1980 much of the marsh still resembled a barren moonscape. Very little biological activity was evident and patches of asphalt-like material were liberally scattered throughout.

With respect to the open-seas fisheries, no definitive biological studies of fish stocks were available. Therefore, the loss period had to be assigned on a somewhat arbitrary basis and included only the period through December 1979, for which period specific data were available when this report was being prepared. Whether or not there were any longer-term effects could not be ascertained. As noted in Chapter 6, some monitoring of effects on the various fisheries in the spill area is continuing.

A second problem concerns the availability of economic data. It would have been desirable to have explained losses to open-seas fisheries using a model reflecting the underlying production relationships, that is, using fish catch and effort data. Unfortunately, the statistics which were available did not provide sufficient detail

to permit a production function approach to be used. It is always difficult to obtain detailed data from fishermen concerning the operations of their vessels, but gathering this information in Brittany was especially difficult because of the artisanal nature of the open-sea fisheries and the system of record keeping which required considerable effort on the part of the investigators to put the available data into a form suitable for analysis. Granting that it will never be possible to obtain ideal data easily, the prospects of obtaining more detailed catch and effort information will be better for countries and fisheries where boats are larger and where a greater proportion of the catch is sold through organized markets than in the open-seas fisheries of Brittany.

Another facet relating to economic data is that no attempt was made to model the demand side of the fisheries markets. Brittany's fisheries represent about 4 percent of the value of French fisheries, and the price effects of supply disruptions in connection with the oil spill were small and temporary. Demand studies of Brittany fisheries would have been a major undertaking, and in view of the relatively minor role of Brittany fisheries in relation to France as a whole, such an effort was not warranted. However, a large oil spill in some locations could affect a significant part of a fishery, e.g., a scallops fishery off the New England coast. In such a case, the change in supply could have a large impact on price, and it would be important to account for price effects to show the distribution of the costs between producers and consumers, as illustrated in Figure 3–3.

Finally, the critical role that fishermen's records play in estimating and obtaining compensation for oil spill damages should be emphasized. In the Amoco Cadiz case and in at least one other oil spill, fishermen had to provide income statements and effort data in order to receive compensation for claimed economic damages.[21] Thus, an important lesson is that fishermen who operate in areas threatened by oil spills should be aware that they must keep detailed income statements and effort data if they hope to receive compensation for damages from an oil spill.

Distribution of Costs

Virtually all of the costs to marine resources shown in Table 3–17 were reimbursed by the French national government to the individual activities involved. Only the damage to fishing boats and equipment and about 50 percent of the damage to real and personal property, together representing about 1 percent of the total costs, were uncompensated. Thus, the costs borne by Brittany amounted to about 1.5 million 1978 francs, plus whatever portion of the remaining costs—about 138.5 million 1978 francs—paid by the national government, was reflected in taxes paid by Brittany to the national government. The latter is discussed in Chapter 7.

Social costs to France equal the total shown in Table 3–17, 140 million 1978 francs. Because the impacts on the marine harvest in Brittany did not affect world prices of the relevant products and because the oil spill did not affect the fishing activities of non-French fishermen, no costs were incurred outside of France, i.e., by the rest of the world.

NOTES

[1] The increased leisure time for the unemployed workers was imputed to have a zero value. The belief is that the forced unemployment was more likely a cost than an advantage to these workers, measured in terms of utility.

[2] About 20 large, i.e., 50 ton, fishing boats operate out of Morlaix. These boats fish for about one week on each voyage, going to the English coast, elsewhere in the English Channel, or the Scilly Isles. They are part of the "industrial" fishing fleet, in which the crew members, about seven on average, are paid wages instead of a share of the catch.

[3] Some oysters remain in the Bay of Morlaix for the totality of their life cycle.

[4] Mr. Guy Berthou, President of the Committee, was particularly helpful.

[5] Data which became available after this report was prepared indicate that oyster production in the estuaries may well not have returned to normal by 1982.

[6] Seaweed is also collected on the beaches by farmers living near the coast, and used as fertilizer.

[7] It is assumed that this harvest was obtained at a somewhat greater cost than would have been expected had normal harvesting been utilized.

[8] The incidental harvest of cast seaweed by farmers was also unaffected by the oil spill, although some delays in harvesting may have occurred. Most of this harvest takes place in the fall, and the oil on the beaches was removed by that time.

[9] These records were obtained and made available by Mr. Henri Didou, Secretary of the Local Committee on Marine Fisheries in Brest. Mr. Didou also permitted the conducting of a mail survey of the fishermen working in the affected area and assisted in interpreting questions relating to catch reports and fishermen's compensation.

[10] This approach is used in Bonnieux, et al. (1980).

[11] Two types of boats, sand boats (sabliers), and seaweed boats (goemoniers), are sufficiently specialized so that they may be excluded from all measures of fishing effort in the data series reported herein.

[12] The practical utility of this approach is argued in a study by Levi (1976).

[13] Scallops are not an open fishery in Brittany. The harvest of scallops was not significantly affected by the oil spill.

[14] Real values of catch were generated by modifying nominal values of catch using the quarterly consumer price index for France, as tabulated in Organization for Economic Cooperation and Development (1980).

[15] The data shown are for the seven of the ten stations in the quartier maritime of Brest affected by the oil spill: Le Conquet, Portsall, Aber Wrac'h, Plouguerneau, Kerlouan, Molene, and Ouessant. Similar data were developed for the other two fisheries groups for the quartier maritime of Brest, and for all three fisheries groups for the four stations in the quartier maritime of Morlaix—Plougasnou, Carantex, Roscoff, and Plouescat—and the two of the four stations in the quartier maritime of Paimpol—Treguier and Lannion—affected by the oil spill.

[16] Appendix B to this chapter contains a discussion of the regression equations for both catch weight and real value of catch and their statistical properties.

[17] The findings of the Autin and Gilly (1979) study are discussed in Bonnieux, et al. (1980).

[18] Cf. Bonnieux, et al. (1980, p. 48), where the officially reported catch for all affected areas taken together is assumed to be 85 percent of the total catch.

[19] An explanation of this problem is presented in Appendix B to this chapter.

[20] For discussions of the method see Maler (1974) and Freeman (1974).

[21] In the Santa Barbara case, fishermen who could not produce income statements were not given compensation.

REFERENCES

Amiand, D., 1979: *L'Ostreiculture Bretonne avant et apres l'echouement de l'Amoco Cadiz,* Ecole des Cadres, Brest, France (unpublished report).

Autin, M., and B. Gilly, 1979: *L'Amoco Cadiz: Relations Systeme Peche Pollution.* Memoire, Ecole National Superior Agronomique, Rennes, France.

Bonnieux, F., P. Dauce, and P. Rainelli, 1980: *Impact Socio-Economique de la Maree Noire Provenant de l'Amoco Cadiz,* Institut National de la Recherche Agronomique, Rennes, France, 248 pp.

Carlson, E., 1973: *Cross Section Production Functions for North Atlantic Groundfish and Tropical Tuna Seine Fisheries,* NMFS Circular 371, National Oceanic and Atmospheric Administration, Washington, D.C.

Coat, Y., 1979: *Goemons et Goemoniers.* Universite de Bretagne Occidentale, Brest, France (unpublished report).

Congar, R., 1981: Unpublished data from government offices provided in personal communication, Universite de Bretagne Occidentale, Brest, France.

Freeman, A. M., 1974: On estimating air pollution control benefits from land value studies, *Journal of Environmental Economics and Management.* 1, 1, 74–83.

Levi, D., 1976: *Fuel Consumption as an Index of Fishing Effort for Small and Medium Range Trawl Fisheries.* FAO Technical Report No. 155, Food and Agriculture Organization, Rome.

Mäler, K-G., 1974: *Environmental Economics.* Johns Hopkins University Press, Baltimore, 280 pp.

Mead, W., and P. Sorensen, 1972: The economic cost of the Santa Barbara oil spill, in *Santa Barbara Oil Spill: An Environmental Inquiry. University of California Marine Science Institute, Santa Barbara, California.*

Organization for Economic Cooperation and Development, 1980: Main Economic Indicators, Historical Statistics, 1960–1979, Paris, p. 296.

Topinka, J., and L. Tucker, 1981: Long-term contamination of fucoid macroalgae following the Amoco Cadiz oil spill, in *Amoco Cadiz, Consequences d'une Pollution Accidentelle par les Hydrocarbures,* Proceedings of the International Symposium at Centre Oceanologique de Bretagne, Brest, 19–22 November 1979, Centre National pour l'Exploitation des Oceans, Paris.

Appendix A

NONCOMMERCIAL MARINE BIOMASS AND SEA BIRDS

Gardner M. Brown, Jr.

INTRODUCTION

In addition to marine resources for which monetary estimates of social costs were made, two other categories of marine resources were investigated. These were (1) lower trophic level marine organisms, termed collectively, noncommercial marine biomass; and (2) sea birds. No estimates of monetary losses associated with these two categories were made, because of the lack of credible methods for doing so. The following discussion describes the nature and extent of the estimated losses in these categories in physical terms.

LOSSES OF NONCOMMERCIAL MARINE BIOMASS

Analytical Problems

When oil spills destroy lower trophic level organisms and alter mortality rates for some period of time thereafter, an ecological imbalance is created. It is believed that the imbalance generally works its way up through the food chain and reduces the equilibrium harvest of commercial species as a consequence of the diminished stocks of the noncommercial species. Economic losses are thereby incurred. Another source of loss to society stems from sorrow, outrage, hopelessness and other feelings of despair people have and express when a man-made oil spill destroys any life. It clearly is a loss because healthy people do not pay to obtain more of these feelings and indeed are observed to spend valuable resources to avoid bearing such emotions in other spheres of life. Ascertaining the money equivalent of emotional losses is beyond the capabilities of present analytical methods. In the United States the task usually is left to judges and juries who reach conclusions in one or more ways not yet codified.

One technique for estimating the monetary loss of noncommercial species would be to ask hypothetical willingness-to-pay and willingness-to-sell questions. This was one of the approaches adopted for estimating losses to recreationists, as described in the next chapter. The major difficulty is in devising questions which can be understood and which elicit truthful answers.

A second technique, adopted notably by the state of California, is to use replacement cost for the lost or damaged biota.[1] Estimates of lost biota and the costs of replacing them are required. One way to estimate the cost is to use the price lists of firms supplying organisms for experiments or supplying animals to zoos. However, there are serious drawbacks to this approach.

How does one value a species for which there has been no exchange? Hypothetical estimates might be obtained but are they valid? The price of an organism to a zoo or a laboratory differs greatly from the price of the organism *in situ,* which is the relevant value. Imbedded in the market price are the costs of collection, storage, and transportation to storage sites or sites of transhipment. These costs are not losses to society. Even the normal profit component is not a cost to society if that profit can be earned by collecting the same organisms elsewhere, which were not destroyed by the spill.

Some might want to argue that because some biomass was lost, it ought to be replaced. If it is not replaced, the damaged parties ought to be given the costs of replacement. This argument might hold in court,[2] but the flaw is that it does not take into consideration the concept of opportunity cost. Suppose to replace a given number of amphipods it takes labor, capital, and other resources which could have produced goods valued at 1 million dollars by consumers. If, indeed, the amphipods are replaced, society will have given up 1 million dollars worth of goods for the replaced amphipods. Society will have made a poor trade if the replaced amphipods are not worth at least 1 million dollars. Water project agencies in the United States have long recognized this idea and have adopted the following standard for use in project analysis: benefits (losses) limit, and are limited by, alternative costs (replacement costs). Replacement cost certainly is an overestimate of benefits in the present instance.

Quantifying the biological relationships of the food chain, ending with commercial species which have economic value, is the third technique for valuing noncommercial species. It is the only approach which can be defended by both the economics and biological professions. An estimate of damages could be based on the value of commercial fish which could have been produced by the biota destroyed. The major shortcoming of this approach is that there is little useful empirical evidence regarding the transformation of prey up through the food chain into estimates of commercial species produced.

A fourth technique for valuing noncommercial marine biota is to value biomass by a market price per pound for a low value species such as a "trash fish." The market price is not the economic value of a fish *in situ*, but that value plus the cost of harvesting resources which have value elsewhere. Including harvesting costs as a component of price can produce a substantial upward bias in the estimate of value. The other drawback of this approach is, of course, the leap of faith it takes to measure one species by the value of another. Few would argue seriously that the value of goldenrod or witchgrass should be estimated by the market price of alfalfa. Almost certainly this technique would create an upwardly biased estimate of unknown magnitude.

The fifth technique is to choose some arbitrary unit value and apply it to the number of organisms destroyed or damaged. This approach actually was used in the S.S. Zoe Colocotroni decision.[4] The judge in the case applied the lowest replacement value per organism, namely, 0.25 FR, to all the organisms in order to make an estimate of total cost. The list of values from which the lowest one was selected was based on prices from biological supply firms. Most recently, on the appeal of the S.S. Zoe Colocotroni decision, the court ruled that the award of damages should not be based on a theoretical replacement cost.[5] Beyond the reiteration that this is an arbitrary technique, there is little to be said on behalf of, or against, this approach.[6]

No valuation approach is both currently feasible and conceptually satisfactory from economic and biological viewpoints. This does not mean that noncommercial marine species are worthless. If, to avoid this conclusion, replacement cost is adopted, as it has been in a number of cases in California, those adopting it should realize that it may satisfy ideas about distributive justice, but it very likely will result in an overestimate of losses.

Estimating Losses of Noncommercial Marine Biomass in the Amoco Cadiz Oil Spill

All approaches to estimating a monetary value for the loss of noncommercial marine biomass first require estimates of the physical losses. In this section the data on those losses for the Amoco Cadiz oil spill are presented.

The most comprehensive and available source of biomass losses is the work of C. Chasse. Immediately after the oil spill, Chasse collected samples of macrofauna in 45 intertidal and subtidal locations, inside and outside the polluted zones, from which he computed mortality rates, population levels, and an index of oil pollution using data from the two types of regions. He then calculated the losses of biomass along approximately 300 kilometers of affected coastline, using clean beaches as a reference level and the quality of oiled beaches sampled at 135 locations.

Losses of benthic biomass were estimated at 60 million individuals or 260 thousand wet tons. Of this total 50 thousand tons and 210 thousand tons were estimated to be intertidal and subtidal, respectively (Chasse, 1979). In terms of species, 20 million were estimated to be *Echinocardium cordatum*, 16 million *Cardium edule*, and 14 million *Mactra corallimax* (Chasse and Guenole-Bouder, 1981). However, some species were omitted from the above estimate. Allowing for these species plus losses of macrofauna would bring the estimated total loss to about 300 thousand wet tons (Chasse, 1981).

The above loss figure is an estimate of the instantaneous or short-run mortality and does not encompass estimates of lost biomass through time as the species begin to recover. Very little work has been done on this aspect of the problem, although individual species in specified locations are being studied (Chasse and Guenole-Bouder, 1981; Bodin, 1978). For example, the density and diversity of ampelisca located in the fine sands of Pierre Noire within the spill area still are below normal according to Cabioch.[7]

The monetary figures below provide some sense of the order of magnitude of the costs involved, using two of the above approaches and hypothetical values. One approach is based on the fact that the Station Biologique Roscoff collects some species which are then sold according to listed prices. This activity is incidental to the research responsibility of the station. Applying these posted prices to the major species affected by the spill yields a loss of about 160 million francs (about 38 million dollars). However, no evidence was found that biota are collected in great numbers in the oil spill region for resale to zoos or to biological supply firms, or that prices to buyers rose as a consequence of the spill.

The other approach is based on the fact that California uses a value of about 1 franc for the replacement value of a sea urchin, one of the species incurring a large loss off the coast of Brittany, i.e., an estimated 20 million. The price of 1 franc is one-sixth the value used by Station Biologique Roscoff. Applying 1 franc per unit as a representative figure to the estimated total loss of 60 million individuals yields 60 million francs (about 15 million dollars). The lowest unit value on the species list is just over 0.04 francs, which, if applied to the estimated numerical loss of 60 million gives a monetary loss of about 2.4 million francs.

These figures represent magnitudes which might be used if the approaches underlying them could be persuasively defended on economic grounds; unfortunately, they cannot be.

EFFECTS ON SEA BIRDS

Analytical Problem

Thousands of sea birds were lost as a result of the Amoco Cadiz oil spill. These birds are not commercially harvested. They are viewed by people only incidentally, if at all. The loss was marginal in the sense that no single species was threatened. Thus, the effect of the spill on man was to change the probability of an incidental viewing by some amount which would have to be estimated.

Even if that probability could have been estimated, the problem of estimating a value of an incidental viewing would remain. There is as yet no credible method for doing so.

Estimating Effects on Sea Birds

In a rigorous study Monnat and Guermeur (1979) estimated actual losses over the period from the time of the spill, 17 March until the end of April, of 19–37 thousand birds. This section discusses the sources and methodology behind their estimate, as well as the important qualitative differences among species regarding absolute losses, relative losses, loss of breeding populations, and long-term prospects.

During previous oil spills affecting the coast of Brittany, only live birds had been systematically collected. This time a decision was made also to collect and count dead birds. Thirty collection centers were established. Those located in the Cotes-du-Nord were organized by the French League for the Protection of Birds and all birds were shipped to a center at Perros-Guirec. Those in the rest of Brittany were under the direction of the Society for the Study and the Protection of Nature in Brittany (SEPNB), with activities centered in Brest. The SEPNB was responsibile for making an overall report. These centers participated in the cleaning of live, oil-soaked birds and registration of birds by species, and time and place found. The center at Brest undertook all the scientific examinations such as autopsies and age determinations. From the day the first center at Brest opened for business on March 20th until the end of April, 4,043 birds—living and dead—were recorded as having been collected by the various centers.

The vast majority of the losses was suffered by three types (Monnat and Guermeur, 1979): 64 percent of the total by auks, puffins, murres, and razorbills; 17 percent by cormorants; and 5 percent by divers. It is not surprising that this was the case. These birds spend most of their time at sea, resting on the water when they are not flying, and dive for their food. Upon coming in contact with oil, they lose the waterproofing that is provided by their outer plumage and the insulation qualities of the inner, down feathers. Birds so affected lose their buoyancy. They must raise their metabolic rate to maintain their temperature. They become susceptible to hypothermia and pneumonia, and may become unable to feed or fly (Boersch, et al., 1974; Bourne, 1968; Vermeer and Vermeer, 1975).

Gannets, petrels, kittiwakes, and shearwaters are sea birds that spend a greater portion of their time in the air than do the auks. The effect of the oil spill on birds in this group would be expected to be less. This is reflected in their considerably lower loss, i.e., 2.4 percent of the total (Bourne, 1968; Monnat and Guermeur, 1979; Vermeer and Vermeer, 1975). Shore birds—including gulls, snipes and sandpipers—and terrestrial birds, are also less likely to be affected (Bourne, 1968; Monnat and Guermuer, 1979). Although these last two groups were underrepresented in the short-term loss figures, they could well be more adversely affected by the long-run effects of oil pollution, as discussed below.

Going from the count of slightly over 4 thousand birds received in collection centers to an estimate of the total number of birds lost and to estimates of the number lost of each species is an inexact art. Rather than simply multiplying the count by factors that had been used in other studies, Monnat and Guermeur (1979) tried to identify the particular sources of over- and underestimation. With respect to the former, some of the 4 thousand birds collected clearly did not die from the Amoco Cadiz spill. For example, about 60 percent of the birds received by the Crozon and Ouest-Leon sectors were puffins. Yet this is an area the spill did not reach. Three-quarters of these birds were received in the first six days after the spill, many in an advanced state of decomposition. The only reasonable explanation is that they died from some other cause. This must also be true of some of the birds received in all the other sectors. Even in years when there are no reported spills, it is common to find dead birds—particularly puffins and razorbills—and sometimes in large numbers, on Western European coasts. They may have died from ingesting oil washed out from ship and tanker bilges and ballasts, from a disease, or from being weakened by extreme weather. Because of the tremendous influx of birds in such a short time, the veterinarians did not have an opportunity to carry out the necessary tests to determine the cause of death. It is believed, however, that 15 to 20 percent of the dead birds found had died of anterior causes.

The sources of possible underestimation are many. Birds may die and never reach the coast; they may reach the coast and not be found; they may be found but not be sent to a center to be counted. To estimate the first source of underestimation, two experiments were performed. One, by Monnat and Guermeur (1979), involved doing a series of simulations using a model developed by Bibby and Lloyd (1977) and Hope-Jones, et al. (1970). This model attempts to predict where birds that become oil-soaked on a particular day and place would come ashore. The simulations did a fairly good job of explaining the pattern of actual arrivals. The simulations also predicted that some birds would be found outside the primary search area, e.g., in southern Brittany, on the Channel Isles, on the Normandy coast,[8] and that some birds would miss land completely and presumably sink in the open seas.

The second experiment was undertaken by G. Mudge of the Royal Society for the Protection of Birds. Banded dead birds were dropped off a ferry at various distances from land and their recovery rates were counted. As would be expected, the relative recovery rate and the date of recovery were inversely related to the distance of the drop point from land. On the average, 23 percent were recovered (Monnat and Guermeur, 1979).

Certainly, not all birds reaching land are recovered. Some come ashore in inaccessible places. Others are covered by oil and debris on the shore and are not seen by searchers. One study showed that trained searchers would miss 20 percent of the dead birds if the beach were searched only a single time (Monnat and Guermeur, 1979). Some of the shore and terrestrial birds might have gone inland to die and have been missed by the searchers; this might well explain some of the low count for these birds.

There are three reasons why birds that were found were not forwarded. One, some centers—notably Trevou-Treguignec and Morlaix in the Cotes-du-Nord region—did not keep count of, or forward, dead birds. This represented a clear loss of information for the study. Two, it appears that the more exotic species were collected by taxidermists. Three, cleanup workers, who presumably found many dead birds, did not cooperate with the data collecting process (Monnat and Guermeur, 1979).

Taking account of possible sources of over- and underestimation and applying what is known about each species (specifically, normal habitat, e.g., whether it is more pelagic or coastal in nature; pattern and period of migration; favored breeding grounds and wintering areas) Monnat and Guermeur (1979) derived different adjustment factors to apply to the actual count of collected birds in each species. For example, for the auks—puffins, razorbills, and murres—it was estimated that the 2,000 auks found, excluding those that might have died from causes other than the Amoco Cadiz, represented only 10 to 20 percent of the actual short-term losses. Using this adjustment factor yields an estimate of 10,000 to 20,000 lost birds in this category. The cormorants, on the other hand, which accounted for about 20 percent of the measured losses, are birds that stay close to shore and it would be relatively easy for the living birds to reach the littoral. It was estimated that the measured losses of cormorants probably underestimated the actual losses by 50 percent, resulting in an estimate of 1,000 to 1,500 lost birds in this category. Thus, taking each group of birds in turn, the final estimate of actual, direct losses of 19–37 thousand birds was derived.

Compared to the million dead birds reported by the *New York Times,*[9] this seems like quite a small number. However, before dismissing the effects of the oil spill on birds, it is necessary to consider two more issues: (1) the qualitative impact of these losses on various breeding colonies; and (2) the possible long-term effects on bird populations.

With respect to the first issue, assume, for example, that only two birds of species X were found dead. If these were the last two birds in a Breton breeding colony, this could be a considerable loss. Estimating such qualitative impacts requires more information than is available. Were the dead birds of a particular species part of a Breton breeding colony or were they migrating back to a more northern colony? What are the normal rates of change in the sizes of these populations from year to year? Were the birds of reproductive age or immature adults?

Using what answers are available to these questions and filling in the gaps with educated guesses, Monnat and Guermeur (1979) came to the following conclusions. The effect on the Breton puffin colony was probably not as severe as might first be thought. It appears, as mentioned above, that much of the puffin mortality occurred out at sea for reasons separate from the oil spill and there was no reason to expect that the Breton nesters would be proportionally overrepresented. Although the Breton puffin colonies are quite small, those elsewhere in the North Atlantic are very large and deaths from this spill would have had no appreciable impact on them. In contrast, the effect on the razorbill was certainly more serious from a world standpoint because it is the rarest of the auks. The major rookery, located in the Sept Isles, was in the midst of the spill. But there is not enough information on the demography of this colony over time to make judgements about the effect of the spill. Other breeding areas were outside the area of the spill.

The case of the murres is similar to that of the razorbills. The major nesting area of this species is located in the Sept Isles and there is inadequate prior information about the size of the colony to estimate the effects of the spill. However, the murres is a much less rare bird than the razorbill and its other rookeries were relatively unaffected. The major cormorant colony is also on the Sept Isles and was perhaps affected. However—as noted one year after the spill—the populations in colonies in other areas of Brittany have been increasing for the last several years, including the year after the spill. There would appear to be a few long-term effects due to lack of breeders. Perhaps the most severe loss to a breeding population occurred among the divers. These birds do not nest at all in Brittany, but the losses among one species, the great northern diver, could represent 16 to 50 percent of the breeding population of this bird in Iceland.

With respect to the second issue, all the species mentioned above, plus the shore and terrestrial birds, are candidates for being susceptible to medium- and long-term effects. Birds whose feathers are touched by oil or oily sand instinctively try to clean themselves by preening. This results to a greater or lesser degree in the ingestion of petroleum, which has been shown to be a source of internal lesions and carcinomas (Beer, 1968). An additional problem is the effect of oil on a bird's ability to reproduce. There may be some decrease in the number of eggs laid and there is certainly a decrease in the number of eggs hatched; eggs that are oiled by a bird's feathers simply do not hatch. In fact, oiling eggs is a common method of bird population control (Vermeer and Vermeer, 1975). The magnitude of the long-term effects of the spill on the different species is related to the amount of time they spend in the contaminated area. Birds that are migrating through or those that winter in Brittany but leave in the spring will be less affected than those that are summer nesters in the area of the oil spill.

A final comment on the effects of oil pollution on birds is merited. During any crisis, such as the spill of the Amoco Cadiz, the hard-working people who clean birds quite rightfully get a good share of the media publicity. This might lead an uninformed observer to think that some of the effects of the oil spill are, if not negligible, reversible, because the birds can always be cleaned. Less than 10 percent of the birds collected after the Amoco Cadiz spill were found alive and were candidates for cleaning. Of those found alive and treated at Brest—the center with the most trained people and using the most recently approved methods for cleaning—only slightly more than one-fourth were released alive. Further, the potential mortality rate of these birds released after cleaning is five times greater than that of birds that have not been through an oil spill (Monnat and Guermeur, 1979). While the success rate for returning oil-soaked birds to their natural habitat is relatively great for cases where an occasional bird is brought to an expert on an individual basis, cleaning birds is a much less successful endeavor in cases of events involving large numbers.

In fact, it is questionable, in a benefit-cost framework, whether cleaning birds after an oil spill is an economically justifiable activity. A study done by LeBail (1980) estimated the cost of treating birds received alive by the center at Brest at about 225 thousand francs. Ninety-five of 314 birds received live at Brest were released, yielding a cost per released bird of about 2,400 francs (about $575). As noted above, released, treated birds have a much higher mortality rate than birds that have never been in an oil spill. If the Amoco Cadiz birds have the same experience of increased mortality as that of birds in a study done in the Netherlands (Monnat and Guermeur, 1979), the cost of treatment per bird still living after two years would be about 5,500 francs (about $1,300).

NOTES

[1] The office of the Attorney General of California, acting primarily on behalf of the California Department of Fish and Game, has been using replacement values since 1971, according to Edward Dubiel in a personal communication, 22 September 1980.

[2] In the 11 August 1980 appeal of Commonwealth of Puerto Rico v. the S.S. Zoe Colocotroni, the judge cited language in the Outer Continental Shelf Lands Act which said that damages are not limited by sums "to restore or replace" natural resources. He argued further that the "concept of restoration" runs strongly through Congressional oil pollution amendments and also cited informative language in the 1977 Clean Water Act amendments, "...'recover the costs of replacing or restoring natural resources;'" and in the legislative history, "the measure of liability is the reasonable costs...in replacing the resources...the measure of liability is the reasonable cost of acquiring resources to offset the loss." Nevertheless, the judge rejected the argument for replacement costs because, as a practical matter, the organisms were not to be purchased and would not survive upon their return to their damaged habitat. See Commonwealth of Puerto Rico v. S.S. Zoe Colocotroni, U.S. Court of Appeals, First Circuit, Nos. 78–1543, 79–1468, 12 August 1980.

[3] Professors Gardner Brown and Vincent Gallucci of the University of Washington, Seattle, Washington, currently are estimating the cost of polycheate losses expressed in terms of its commercially valued flatfish predator.

[4] Commonwealth of Puerto Rico v. S.S. Zoe Colocotroni, 456F, Supp. 1327, Federal District Court of Puerto Rico, 1978.

[5] Commonwealth of Puerto Rico v. S.S. Zoe Colocotroni, U.S. Court of Appeals, First Circuit, Nos. 78–1543, 79–1468, 12 August 1980.

[6] There is another technique, namely, analysis of implicit values of decision makers as revealed in voting for appropriations for refuges, species preservation, etc. In order for this technique to be plausible, one would have to equate, in some fashion, the destroyed biota, such as amphipods, with the preserved species, such as the furbish lousewort. In addition, destruction of a species is a quite different matter, biologically and economically, than destruction of some members of an unthreatened species.

[7] Interview with L. Cabioch, Station Biologique de Roscoff, Roscoff, France, 17 June 1980.

[8] Notable discoveries were made in these areas.

[9] A report in the *New York Times* of 2 April 1978 stated that, "...over a million birds died within days of the [Amoco Cadiz] oil spill."

REFERENCES

Beer, J.M., 1968: Post-mortem findings in oiled auks dying during attempted rehabilitation, in McCarthy and Arthur, editors, *The Biological Effects of Oil Pollution on Littoral Communities*. Proceedings of a Symposium held at the Orielton Field Centre, Pembroke, Wales, 17–19 February 1968, Field Studies Council, London, 123–129.

Bibby, C.J., and C.S. Lloyd, 1977: Experiments to determine the fate of dead birds at sea. *Biological Conservation*. 12, 4, 295–309.

Bodin, P., 1978: *Etude d'Impact de la Pollution par les Hydrocarbures sur les Peuplements Interstitiels*. Institute d'Etudes Marines, Universite de Bretagne Occidentale, Brest, France.

Boersch, D.F., C.H. Hershner, and J.H. Milgram, 1974: *Oil Spills and the Marine Environment*, Ballinger Publishing Company, Cambridge, Mass.

Bourne, W.R.P., 1968: Oil pollution and bird populations, in McCarthy and Arthur, editors, *The Biological Effects of Oil Pollution on Littoral Communities*. Proceedings of a Symposium held at the Orielton Field Centre, Pembroke, Wales, 17–19 February 1968, Field Studies Council, London, 99–121.

Chasse, C., 1979: *Bilan des Pertes en Biomasse des Divers Compartiments de l'Ecosysteme Benthique Evolution in Mileu Rocheux*, Institut d'Etudes Marines, Universite de Bretagne Occidentale, Brest, France.

Chasse, C., 1981: Les dimensions spatiales et temporelles de la perturbation de l'ecosysteme littoral par le petrole de l'Amoco Cadiz, lecons et propositions, in *Amoco Cadiz, Consequences d'une Pollution Accidentelle par les Hydrocarbures*, Proceedings of the International Symposium at Centre Oceanologique de Bretagne, Brest, 19–22 November 1979, Centre National pour l'Exploration des Oceans, Paris, 359–380.

Chasse, C., and A. Guenole-Bouder, 1981: Comparaison quantitative des populations benthiques des plages de St-Efflam et St-Michel-en-Greve avant et dupuis le naufrage de l'Amoco Cadiz, in *Amoco Cadiz, Consequences d'une Pollution Accidentelle par les Hydrocarbures*, Proceedings of the International Symposium at Centre Oceanologique de Bretagne, Brest, 19–22 November 1979, Centre National pour l'Exploration des Oceans, Paris, 347–357.

Hope-Jones, P., G. Howells, F.I.S. Reese, and J. Wilson, 1970: Effect of Hamilton Trader oil on birds in the Irish Sea in May 1969. *British Birds*, 63, 3, 97–110.

LeBail, J., 1980: Impact de la pollution de l'Amoco-Cadiz sur les oiseaux marins, Universite de Bretagne Occidentale, Brest, France (unpublished manuscript).

Monnat, J.Y., and Y. Guermeur, 1979: L'Amoco-Cadiz et les Oiseaux. Societe Pour l'Etude et la Protection de la Nature en Bretagne, and Ministere de l'Environment et du Cadre de Vie, Brest, France (unpublished manuscript).

Vermeer, K., and R. Vermeer, 1975: Oil threat to birds on the Canadian west coast. *The Canadian Field Naturalist*, 89, 3, 278–298.

Appendix B

CORRECTING FOR AUTOCORRELATION PROBLEMS IN REGRESSION EQUATIONS USED TO ESTIMATE LOSSES IN FISHERIES CATCH

AUTOCORRELATION PROBLEMS

The model used to estimate losses in fisheries catch employs time series data to estimate the coefficients for the explanatory variables, i.e., trend in catch and seasonal variations around that trend. These coefficients are used in the period following the oil spill to create a series of forecasted (expected) catch figures, from which monthly losses in catch are computed. This methodology assumes that the error terms of the estimated equations, u_t, are independent of each other. If these error terms are not, in fact, independent of one another, the estimated equations will have autocorrelation problems, and the conventional assumptions underlying ordinary least squares estimation will be violated.

The problem may be represented formally as follows. Suppose the true relationships among the variables are represented by the model:

$$C_t = \sum_{i=1}^{k} B_i X_{it} + u_t + \sum_{i=1}^{n} Z_i u_{t-i} \ (n < T), \qquad \text{(3B-1)}$$

where

- C_t = catch at time t;
- B_i = coefficients of the k explanatory variables;
- X_{it} = value of the i^{th} explanatory variable at time t;
- u_t = error term at time t;
- u_{t-i} = the error term for lag i whose coefficient is Z_i; and
- T = the total number of observations in the time series.

If C_t is functionally related to the lagged error terms, this indicates that autocorrelation is present in the time series. In this case, the ordinary least squares estimates of expected catch will still be unbiased, but the variance of these estimates will be high as compared to those produced by an estimation model which corrects for the autocorrelation problem. In short, the presence of autocorrelation increases the forecast error of ordinary least squares estimated equations.[1]

If the true values of the coefficients of the lagged error terms, i.e., the Z_i's, were known, it would not be difficult to transform the input data in such a way as to give coefficient estimates of the explanatory variables with properties very close to those of ordinary least squares estimates where the error terms satisfy the conventional assumptions.[2] There are, however, three problems which prevent such an optimal transformation from being obtained. One, if k is the order of the highest error lag specified, the first k observations in the time series cannot be used for estimation purposes. Two, the true lags for the error terms are generally not known; thus some judgement has to be applied for lag selection. In terms of equation (3B–1), this amounts to identifying the Z_i's which are not equal to zero. Three, once certain lags have been specified, the coefficients of the lagged error terms and of the explanatory variables have to be estimated simultaneously. This involves minimization of a non-linear equation using iterative techniques. Consequently, t-values and F-ratios for the estimated equations are only approximately valid.

In the absence of an optimal transformation function, the equations in the forecasting model have been estimated using the AUTOREG procedure of the Statistical Analysis System.[3] In order to select those Z_i's which are not equal to zero, estimates were used of the autocorrelations between error terms for lags up to and including twelve months, i.e., correlation coefficients between any particular error term, u_t, and the errors $u_{t-1}, u_{t-2}, \dots u_{t-12}$.

Appropriate lags were selected on the criterion of high autocorrelation for any specified lag i, which would imply that Z_i is very likely not equal to zero. Afer having selected appropriate lags using this criterion, the equations were all reestimated using the AUTOREG procedure. The autocorrelations of AUTOREG estimated equations were then examined in order to verify the fact that the autocorrelation problem had been substantially reduced or eliminated from the final forecasting equations, although it is never possible to reject with certainty the hypothesis that some autocorrelation still exists.

CONFIDENCE INTERVALS

The procedure which is used to predict fishery catches in this report falls under the heading of conditional forecasting, i.e., forecasting when one or more of the explana-

tory variables are unknown in the forecast period. The trend variable, year, and the monthly dummy variables, are all known for the post-oil spill period. If k is the lowest order lagged error term included in the forecast equation, then the point predictions for catch in the period from the oil spill *through period k* have the properties of being the best linear unbiased predictors.[4] But lagged error terms of order k are not known beyond the kth period following the oil spill. Because the forecast period of 20 months exceeds the lowest order lagged error term included in the forecast equations, the magnitude of some of the error terms cannot be known. The value of each of these error terms has been fixed equal to zero, which is its expected value. This approximation is reasonable when producing point estimates. However, confidence intervals for point estimates are not judged to be meaningful, given the error introduced by this approximation.

NOTES

[1] See Johnston (1963, Chapter 8).

[2] See Johnston (1963, pp. 259–261).

[3] The AUTOREG procedure computes least squares estimates in a manner similar to the Cochrane-Orcutt technique. See Johnston (1963, pp. 261–262) and R. Pindyck and D. Rubinfeld (1976, pp. 111–112).

[4] See Johnston (1963, pp. 256–266).

REFERENCES

Johnston, J., 1963: *Econometric Methods.* 2nd ed., McGraw-Hill Book Co., New York.

Pindyck, R., and D. Rubinfeld, 1976: *Econometric Models and Economic Forecasts.* McGraw-Hill Book Co., New York.

Chapter 4

RECREATION: TOURISTS AND RESIDENTS

Gardner M. Brown, Jr., Richard Congar, and Elizabeth A. Wilman

INTRODUCTION

Markets and prices are vitally important for determining values in quantitative monetary terms. Stock markets, farmers' markets, supermarkets, and published price lists are familiar to all. However, the prices and values of some goods and services are elusive, largely because organized markets for their exchange do not exist or are not readily observable. When prospective tourists to Brittany went elsewhere because of the Amoco Cadiz oil spill, or changed their activites, their expected welfare must necessarily have decreased or they would have chosen the alternative of going elsewhere, or engaging in other activities, in the first place. Similarly, residents of the coastal zone of Brittany suffered some welfare losses as a result of effects of the oil spill on their recreational activities. These welfare losses represent the social costs associated primarily with recreation. They cannot be calculated directly from market prices. Various methods are available for estimating these social costs. Several were applied in the study of the Amoco Cadiz oil spill and are described below.

It should be obvious that the existence of losses or benefits reflected in an individual's action or inaction are not always registered directly in the market place. There is, therefore, no justification for assuming or asserting that goods and services have zero value if they are not traded in markets.

One may accept the idea that non-market valued costs and benefits exist, yet object to their quantification on moral or professional grounds. Moral issues are not within the scope of this report. Professional objections relate to acceptability of methods used and accuracy of estimates produced in a study. If judicial codes, case law, and legislative statutes require quantitative estimates of costs for the purpose of compensation, yet omit—on whatever grounds—an estimate of non-market valued costs, the procedure gives these non-market activities an estimated value of zero by default. In courts and legislative settings the issue should not be whether one should estimate or not, but whether the adopted estimation procedures give estimates that are more or less accurate than zero.

This chapter focuses on those social costs identified in Chapter 1 related to recreational activities in Brittany, by both tourists and residents. Three categories of these costs related to responses of recreationists to the oil spill were identified and then were estimated. First, an estimate was made of the non-market valued costs incurred in 1978 by tourists who had planned to come to Brittany but went elsewhere because of the oil spill. Second, estimates were made of the non-market valued costs incurred by tourists who came to Brittany but changed their activity patterns and the beaches they visited as a result of the oil spill. The changes in activity patterns resulted in some loss in welfare (satisfaction). With respect to these two categories tourists were defined as those who remained at least five days in Brittany, and who stayed in hotels, campgrounds, second homes which they owned, in rented rooms or houses, or with friends or relatives.[1] The third category involved residents of coastal Brittany who changed their recreational patterns as a result of the oil spill, thereby incurring some losses.

ESTIMATING THE REDUCTION IN TOURISTS TO BRITTANY IN 1978

Estimating the reduction in the number of tourists going to Brittany in 1978 because of the oil spill is made particularly difficult by the varied sources of, and incomplete, data. For example, no accurate, detailed estimates are available of the total number of tourists and their origins in any year along the coast and in the interior of Brittany. There are bits and pieces of data, e.g., the number of beds in selected communes, the numbers of tourists in parts of Brittany for a given year or season, and the estimated number of summer visits of four or more nights duration by French citizens only based on an annual survey in the fall of summer activities.

Judging from all reports produced after the spill it is clear that there was a reduction in the number of tourists who went to Brittany in 1978, in comparison to what would have been expected in the absence of the oil spill. During some periods, e.g., the early summer, and in some geographic locations, hotel vacancy rates were double the previous year. Tourism in hotels was said to have been the worst in 20 years (Bonnieux and Rainelli, 1980). Not all of this loss can be attributed to the oil spill. The first part of July was the coldest it had been at that time since 1954, and the accumulated rainfall was double that

of the previous year (Cormier and LeMoal, 1980). Not enough data exist to distinguish weather or publicity effects from the impact of the oil spill itself on tourism, nor from the impact of economic conditions, which constitute an important factor affecting tourism. Several documents suggest that selected occupancy rates during August were about the same as for previous years but rates were lower in other months in 1978 (Cormier and LeMoal, 1980).

To derive an estimate of the reduction in visits in 1978 it was assumed that the number of tourists who came to Brittany in 1979 represented the normal number, i.e., reflected the number who would have come in 1978 if the oil spill had not occurred. Table 4–1 shows the number of tourists estimated to have visited the Brittany coast in July and August of 1979. Using the estimate that three-fourths of the total visits occur during July and August yields an estimated 2.32 million tourists to the Brittany coast in 1979.[2]

Estimates of the numbers of tourists to the Brittany coast in 1978 were then made by applying to the 1979 data, estimates of reductions in occupancy rates for the three categories of accommodations shown in Table 4–1. Hotel occupancy rates were down 8 to 10 percent in 1978 relative to 1979 (Cormier and LeMoal, 1980). In Finistere, campsite occupancy in 1978 was 85 percent of that in 1977, according to the Comite Departmental de Developpement et d'Amenagement du Finistere (1979). Because this was the only figure available, it was used for the whole region.[3]

Very few data were available on occupancy of second homes and rentals of residences, apartments, and rooms. Because many of these facilities are owned by people with strong family ties to Brittany, it may reasonably be assumed that such people would be more likely to return during the year of an oil spill than those people who camp or stay in a hotel. Therefore, a range of 5–10 percent decrease in the occupancy rate was assumed for the "other" category.

Table 4–2 shows the estimated reductions in the number of tourists in 1978 attributed to the oil spill, by type of accommodation. Use of the midpoint of the range for the "other" category, 7.5 percent, yields estimated reductions of about 0.185 million for the July plus August period, and about 0.245 million for the year. The latter estimate and the assumed total number of tourists of 2.32 million for the entire year yield an estimate of about 2.07 million tourists who did come in 1978. These tourists were assumed, on the average, to have suffered some loss in satisfaction.

These estimates do not take into account variations in visitors from the interior of Brittany, who account for about 20 percent of the total number of visitors to the Brittany coast. It was arbitrarily assumed that this omission offsets the reduction in the number of tourists in 1978 because of poor weather.

The basic assumption underlying the use of 1979 data is that the net effect of weather and the oil spill in 1978 was to arrest growth in the number of the tourists for one year, so that actual visitation in 1979 was what it would have been in 1978 in the absence of the spill. Further, it was assumed there would be no reductions in visits beyond those in the first year, i.e., 1978. The magnitude of the downward bias this assumption creates is not known. Bonnieux, et al. (1980) estimated a 17 percent decline in tourist activity during 1978, compared with data and trends in previous years. The estimate was based on the difference between actual and predicted sales of flour, based on an analysis of time series data for the period 1970–1978. Their estimate of 17 percent, which assumed no reduction in number of tourists because of poor weather, compares with the above estimate of 11 percent, which did make some allowance for the poor weather experienced in 1978. Applying the Bonnieux, et al., percent decline to the estimated total number of tourists in 1979 produces a reduction of about 0.38 million tourists. Thus, 0.245 million and 0.38 million represent two estimates of the reduction in number of tourists in Brittany in 1978 because of the oil spill, i.e., tourists who had planned to come, but did not come.

Table 4–1.—Estimated Visitors to the Brittany Coast, by Type of Accommodation, July and August 1979.

Type of Accommodation	Number, x 10^6	Percent of Total
Hotels	0.14	8
Camping	0.68	39
Other	0.92	53
TOTALS	1.74	100

Source: Cormier, H., and R. LeMoal, 1980: La saison estivale 1979 en Bretagne, Institut National de la Statistique et des Etudes Economiques, Service d'Etudes de la Direction Regionale de Rennes, Octant No. 1, Rennes, France (February).

Table 4–2.—Estimated Reduction in Number of Tourists to Coastline Area of Brittany, 1978 Compared with 1979.

Type of Lodging	Estimated Number of Tourists in 1979, x 10^6	Assumed Decrease in Occupancy Rate (%)	Estimated Reduction in Number of Tourists in 1978, x 10^6
Hotels	0.14	10	0.014
Camping	0.68	15	0.101
Other	0.92	5-10	0.046 - 0.092
Total, July and August	1.74	--	0. 16 - 0. 21
Total, year	2.32	--	0.21 - 0. 28[a]

[a] Midpoint of range, i.e., 0.245, is used in subsequent calculations.

ESTIMATING THE UNIT LOSS TO TOURISTS IN 1978

Tourists Who Did Not Come to Brittany

The estimate of the loss associated with each forgone tourist visit was based on the costs incurred by foreign tourists who had planned to vacation on the Brittany coast in 1978, but did not do so. About 20 percent of the tourists in Brittany are from outside France. Of these, more come from the Federal Republic of Germany[4] than from any other country. In 1978, some individuals in this group canceled their plans and went elsewhere. Estimates of cancellations vary, but almost certainly there was a significant reduction in foreign tourists in 1978, both inside and outside the oil spill area.[5]

Obviously those who did not come could not have been interviewed in Brittany in 1978. But interviews during 1979 in Brittany also might exclude a substantial fraction of foreign tourists if they had stayed away in 1979 as well as in 1978. French authorities refused to release the names of foreign tourists in Brittany during 1979, and there were insufficient funds to sample any of the countries from which tourists came to Brittany. Although foreign tourists are a significant component of all tourists, they are a very small fraction of the population in any one country.

Because German tourists were the largest group of tourists coming to Brittany from outside France, it was decided to concentrate on those tourists in order to make an estimate of the loss associated with each tourist visit forgone. To obtain a useful sample in Germany of former tourists to Brittany would have been prohibitively expensive. Therefore, the approach adopted was to interview German tour operators, as proxies for the tourists themselves.

Seventeen German tour operators were interviewed.[6] Although these seventeen handle the bookings of but a small fraction of all German tourists to Brittany, it was assumed that they and their clients were representative. Some of the individuals interviewed were employed by agencies with offices throughout Germany and spoke for all offices. As a group, those interviewed were extremely cooperative and helpful, taking time from their busy schedules to be interviewed and to search through records and documents to provide information. The thought they gave before answering questions, and the high level of balance and professionalism reflected in the quality of the answers to the open-ended and subjective questions posed, were impressive.

Not surprisingly, the information was provided with the understanding that data for individual firms would not be revealed. There were important qualitative differences in the packages offered by the firms. These ranged from air travel and expensive hotel accommodations to summer foreign language learning visits for young German students living with French families. Nevertheless, some generalizations were possible from the responses; exceptions are noted.

The average duration of summer season visits was 2–3 weeks. The number of people who made repeat visits to Brittany varied greatly among the firms interviewed. Agencies with a large clientele reported a return rate from 20 percent to as high as 50 percent.

All agencies learned of the oil spill in March. The major sources of information were the press and television. Those firms with substantial business in Brittany, such as Jean Jacq, Swiss Chalets, and Sharnow, and most of the firms offering educational tours to programs for teenagers, had reports on the state of beaches directly from employees or mayors in Brittany. A majority of those interviewed were highly critical of the French tourist office from which they sought information. Written requests were unanswered, or the responses came too late to be helpful. The large tour operators did receive

accurate information from their own sources, as judged by their descriptions of the quality of the beaches throughout the late spring and summer.

Immediately after the oil spill, clientele of the agencies began calling to inquire about it. Those agencies with authoritative information seemed able to quiet the fears of many of their clients. Nevertheless, cancellations began immediately. Interviews with the seventeen tour operators indicate that 40–50 thousand German tourists canceled their plans to visit Brittany during the summer of 1978.

In some cases, typically for the agencies doing a modest business in Brittany, cancellations ran as high as 80 to 90 percent. For the large tour operators with bookings in Brittany of around 1,000 or more trips, cancellations ran about 30 percent. In connection with these cancellations it is very important to note that the clientele of the agencies had signed contracts. Thus, a cancellation could mean as much as a 100 percent loss of the price of the tour, though in most cases the loss would be less than 50 percent. In one case it was the deposit of about 100 francs. Cancellation rates were much higher for those who had made no contractual commitments to visit Brittany.

Some clients rebooked to visit Brittany later. Others rebooked for other resorts, almost always in France, according to the agencies who responded to this question. A few remained at home.

One very large tour operator who kept careful records reported that cancellations ran 40 percent in the northern part of Brittany where the beaches were undamaged. Not many of these cancellations could have been due to poor weather, because the contractual commitment of the individual tourist to this agency was substantial. Very likely the cause was poor information about the location of the spill and the locations of the areas affected. Tour operators were united in their criticisms of media coverage. The media were accused of seeking out the sensational aspects of the oil spill. Facts about the location, extent, and magnitude of the spill either were missing or were distorted. For many a prospective tourist it was difficult to know unambiguously about the quality of the beach near his planned destination. This was the main reason for the cancellations outside the oil spill region. It should also be noted that most of the smallest operators and nearly all the large operators ranked the beach as the most or second most important consideration in choosing Brittany. However, Dr. Wulf's, a large tourist agency, also spoke of the totality of Brittany—its old buildings, good food, and lovely countryside as well as its beaches—as being attractive to tourists.

The tour operators were asked whether the tourists would have been willing to have paid more money to have the same level of experience as was expected of the visit to Brittany. Three responses were obtained: (1) tourists would not pay more; (2) tourists would pay an additional amount of between 3 and 10 percent of the cost of their tour package; and (3) tourists would pay an additional amount of between 10 and 20 percent.[7] The magnitude reported seemed to be independent of the cost of the tour or the size of the agency. A reasonable single figure to use as the cost to tourists who did not come because of the spill would be about 5 percent of the cost of their tour packages. The total cost of these packages varied in 1979 from about 770 francs to about 4,600 francs for two weeks. For an average visit of 2 to 2½ weeks the cost was estimated to be about 3,800 francs. Combining the 5 percent figure selected as a measure of a tourist's willingness-to-pay with the average tour cost of 3,800 francs yielded about 190 francs as the unit loss in welfare, or the social cost of one tourist's forgone visit.

Tourists Who Did Come to Brittany

Valuing the losses incurred by those who came to Brittany in 1978, but whose satisfaction was reduced by the oil spill, is even more difficult than valuing the losses incurred by those who did not come. These losses are related to the willingness of individuals to pay for recreational experiences.

Two analytical methods were used to obtain monetary estimates of losses to tourists who came, in terms of willingness-to-pay. The first was the Hotelling-Clawson travel cost method. This method relates differences in rates of participation to differences in costs borne by individual tourists. From this relationship a demand curve is derived.

The second analytical method involved asking respondents hypothetical questions to elicit their willingness-to-pay for, or be compensated for, changes in the quality of their recreational environments. In this fashion, monetary measures of the compensated or equivalent variation measures of consumer surplus associated with changes in beach quality were obtained.

Travel Cost Method

The travel cost method was adapted by Clawson from the work of Hotelling and further refined through the subsequent work of many researchers.[8] It essentially relies on the fact that on-site recreation is complementary to the goods and services that must be used to obtain it, although the level of utility provided by these complementary goods and services is usually assumed to remain constant as the level of these required goods changes. The dominant factor included in the complementary goods and services is travel. The prime reason for variation in the required amount of travel to a particular recreation site (area) is geographical dispersion of tourists.

The travel cost approach is usually site-specific. However, in this analysis the region was treated as if it were one specific site. It was also assumed that each trip to the region was a single destination trip to a single central point on the Brittany coast, the town of Brignogan-Plage. That is, the Brittany coast was the destination and not

one of several or many destinations on an extended trip. The validity of this assumption is not known.

For a given recreation site—in this case the Brittany coast—this approach uses differences in participation rates resulting from differences in travel costs to visit the region, to estimate the willingness-to-pay to visit the region. Geographic origins of tourists are grouped into zones within which travel costs to Brittany can be assumed to be relatively homogeneous. Then the visit rate per unit of zone population is calculated for each zone. Assuming that tourists across zones are relatively homogeneous, and that tourists within a given zone are not different from other individuals in that zone, the functional relationship between travel cost associated with the zone and the visit rate for the zone gives the *form* of the representative individual's demand curve for visiting the region. To make this individual demand curve zone-specific, the travel cost for that zone must be netted out. Once zone-specific demand curves are obtained for representative individuals in a zone, aggregation across tourists within and across zones is possible and will give the aggregate demand curve, and the aggregate willingness-to-pay, for visiting the region.

The intent in using the travel cost approach was to compare individual and aggregate demand curves for the Brittany coast for the years 1978 and 1979. The hypothesis was that, during 1978 when the oil spill occurred, individual and aggregate demands would be reduced and hence would be less than in a "normal year" such as 1979. Specifically, it was hypothesized that either (1) visit rates would be consistently lower in 1978 than in 1979; or (2) although visit rates from zones adjacent to Brittany might be as high in 1978 as in 1979, visit rates from the farther zones would be lower in 1978, because individuals and households with higher travel costs would hesitate to travel to a region in which the quality of the beaches was uncertain.

Basic data for application of the travel cost method were obtained in two surveys, one each in 1978 and 1979, conducted by the French Institut National de la Statistique et des Etudes Economiques (INSEE)[9], and in a 1979 survey conducted by the firm Organisation des Developpements Economiques et Sociales (ODES). The analyses using the INSEE data are discussed in this section, those using the ODES data in the next section.

Travel Cost Method: INSEE Data. INSEE conducted surveys of tourists in Brittany excluding those staying in hotels but including those staying in communes both inside and outside the oil-damaged zones. For 1978 and 1979, the samples comprised, respectively, 1,199 and 4,024 usable interviews. The INSEE samples specifically included no foreign tourists, although several hundred would have been expected in purely random samples of 1,000 to 4,000 tourists.

On the basis of data from these samples and 1975 population data, visit rates—visits per 10^7 population in the region—were calculated for 21 of the 22 regions of France.[10] These visit rates were then used in regression analyses for each of the two years. In these analyses visit rate was the dependent variable. The independent variables were travel cost from the region to Brittany and travel cost from the region to the nearest alternative French coastal site. The travel cost for each region was the distance in kilometers times a cost of 1 franc per kilometer. The distance to Brittany was that between the main city in each region and Brignogan-Plage in Brittany. The main city used for each region is listed in Table 4–3, along with the distances from that city to Brignogan-Plage and to the nearest alternative French coastal site.

The best-fitting equations selected for 1978 and 1979 were based on the likelihood ratio test. These equations were used to predict visit rates for the respective years, by varying travel cost to Brittany in increments of 100 francs, *first* for a travel cost of 100 francs and *second* for a travel cost of 500 francs. The results of the predictions were that the closer zones had higher visit rates in 1978 than in 1979, but the farther zones had lower visit rates in 1978 than in 1979.

It may well be that variables affecting the differences in visit rates between 1978 and 1979, other than the Amoco Cadiz oil spill, were excluded from the analysis. Differences in weather are one example. In addition, visit rates normally would be expected to show increases from year to year as real incomes increase, if the relative price of recreating in Brittany and prices of other expenditure options did not change, and assuming no change in social tastes. However, with recent substantial increases in gasoline prices, the relative prices of recreating in places like Brittany and of engaging in alternative activities might well have changed, resulting in a diminution of the visit rate increases, especially for the more distant zones.

Yet the data showed a greater increase in the visit rate for farther zones than for closer zones in 1979 relative to 1978. This could occur if a relatively greater fraction of normal visitors from distant origins stayed away from Brittany in 1978 compared to those located closer to Brittany. The more distant prospective visitors presumably have more possible substitutes. Those who did go to Brittany from more distant origins might have stronger ties to Brittany than those who did not. The ties are likely to be more family- than beach-related. Thus, those who went to Brittany in 1979 from a more distant zone had a greater beach orientation than those who went in 1978. There is therefore some reason to attribute the pattern of differences in visit rates between 1978 and 1979 at least partly to the Amoco Cadiz oil spill. Because it seems as reasonable as any other assumption, it was assumed that all of the difference between the visit rates in the two years could be attributed to the oil spill.

Even with the above assumption, problems in obtaining accurate individual demand curves for vacationing on the Brittany coast remained. First, the travel costs were underestimated, because time costs were omitted. As-

Table 4-3.—Data Used in Regression Analyses for Travel Cost Method with INSEE Data.

Region	Main City in Region Used to Compute Travel Cost to Brittany	Distance from Main City in Region to Brittany (km)[a]	Distance from Main City in Region to Nearest Alternative French Coastal Site (km)[a]
Nord	Lille	600	500
Picardie	Amiens	500	500
Region Parisienne	Paris	500	400
Centre	Orleans	500	300
Normandie (Haute)	Rouen	400	400
Normandie (Basse)	Caen	300	300
Bretagne	Rennes	100	100
Pays de la Loire	Nantes	300	100
Poitou-Charentes	Poitiers	400	100
Limousin	Limoges	500	300
Aquitaine	Bordeaux	500	200
Midi-Pyrenees	Toulouse	700	100
Champagne	Reims	600	600
Lorraine	Nancy	800	600
Alsace	Strasbourg	900	700
Franche-Comte	Dijon	800	500
Bourgogne	Besancon	700	500
Auvergne	Clermont-Ferrand	600	300
Rhone-Alpes	Lyon	800	300
Languedoc	Montpellier	800	100
Provence-Cote d'Azur	Marseille	1000	100

[a] Distances rounded to nearest 100 kilometers.

suming the same time was spent visiting in Brittany by visitors from all regions and assuming a reasonably constant opportunity cost of time across vacations, only travel time imposes a time cost.[11] However, because there was no basis on which to make estimates of travel time costs, these were omitted.

Second, the visit rates were based on data from relatively small samples drawn from the 1978 and 1979 populations of summer visitors. How representative—in terms of distribution of origins—the samples were of summer visitors, or of visitors in other seasons of the year, is not known. To derive imputed visit rates related to *total* visitors in each year, it was assumed that the same distribution of origins of visitors would pertain in the total population of visitors in each year as in the sample of visitors. Therefore, the visit rates for the sample in each year were adjusted by the relevant sampling fraction to yield imputed visit rates for each region.

Using the imputed visit rates for each region, demand curves for the representative individual in each region were estimated. For example, consider the Nord region which has a travel cost to Brittany of about 600 francs and a travel cost to the alternative site of about 500 francs. The 1978 and 1979 demand curves for a representative individual in Nord are shown in Figure 4–1. The area under the 1978 demand curve represents the 1978 consumer's surplus, and the area under the 1979 demand curve represents the 1979 consumer's surplus, for the representative individual in Nord.[12] The difference in consumer's surplus, that for 1979 minus that

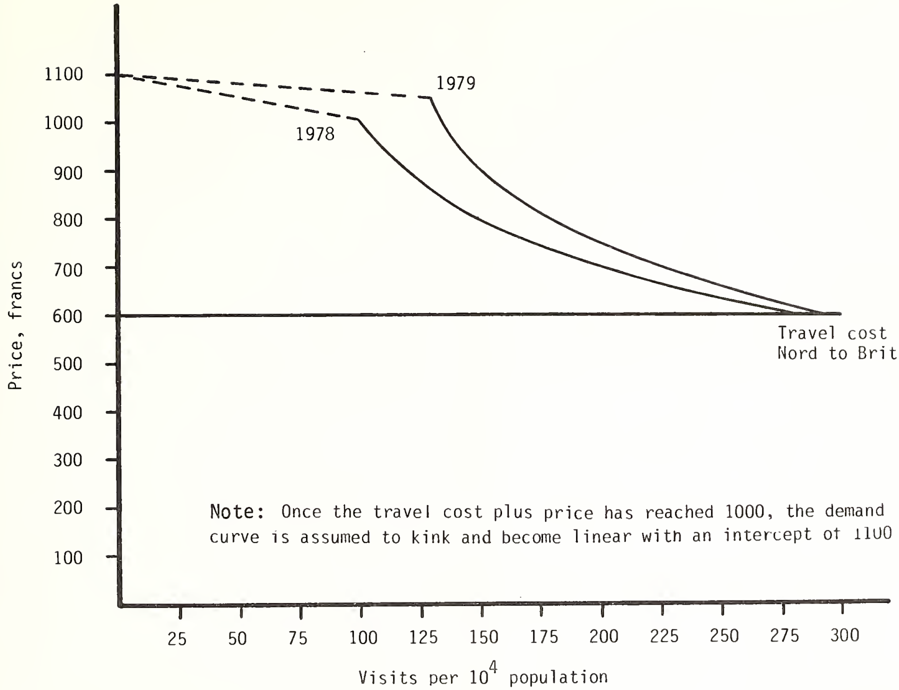

Figure 4–1.—Estimated Demand Curves for Recreation in Brittany for Nord Region, 1978 and 1979.

for 1978, represents the individual loss in satisfaction in 1978 as a result of the oil spill. The same procedure was followed for the other regions.

Multiplying the individual consumer's surplus for each region in 1978 and 1979 by population in the region—assumed to be the same in both 1978 and 1979—yields the aggregate consumers' surplus for each region for 1978 and 1979. The difference for each region represents the net benefits to consumers in the region in 1979 compared with 1978, presumably the net benefits of not having had the 1978 oil spill in 1979. Aggregating over all consumers and all regions, the estimated net difference between 1979 and 1978 in total consumers' surplus for visitors to Brittany was about 6 million francs. For the approximately 2 million visitors in 1978 this yields an estimated loss in consumers' surplus of about 3 francs per visitor.

Travel Cost Method: ODES Data. To obtain additional data for the application of the travel cost method and to obtain data for the direct willingness-to-pay (sell) analyses, a special survey[13] was designed and conducted in the summer of 1979. To find and conduct the survey several market research organizations in France were identified by professional colleagues in the United States and in France. These firms were interviewed, and Organisation des Developpements Economiques et Sociales (ODES) was chosen.

Minimum quotas for specified categories of respondents (French and foreign) were specified and filled by interviews at the place of accommodation or residence. The resulting sample of 588 is shown in Table 4–4.

The total sample size was limited by available funds. Foreign tourists were sampled roughly in proportion to their representation, 20 to 25 percent, in the total population of tourists. Twice as many tourists as residents were interviewed because of the need to partition the tourists, yet obtain statistical significance in data thought to have a large random component.

Procedure and Results. Application of the travel cost method with INSEE data involved the use of actual dis-

Table 4-4.—Categories of Respondents in ODES Survey.

	Polluted Region	Non-Polluted Region	Total
Tourists			
French	206	100	306
Foreign	54	30	84
SUBTOTAL (Tourists)	260	130	390
Residents	187	11	198
TOTAL	447	141	588

tances traveled by tourists from points of origin to a specified destination in Brittany. In contrast, the data produced in the ODES survey involved hypothetical travel costs. That is, individuals in the sample of 390 tourists in Brittany in 1979 were shown pictures of polluted beaches and were asked a sequence of questions with respect to whether they would travel 20 kilometers, 50 kilometers, and so on, to a clean beach, and if so, how often.

On the basis of the answers received, and a travel cost of 1 franc per kilometer, a "willingness to incur increased travel costs to avoid pollution" function for households was estimated. This function was assumed to be equivalent to a willingness-to-pay function for clean beaches. The answers to the questions and additional information on the respondents' current behavior patterns allowed the determination of points for that function, such as **b**, **c**, and **d** in Figure 4–2, for each respondent. Joining these points with straight line segments and projecting the segment **bc** to the vertical axis gave an approximate household (family) willingness-to-pay function.

The area **hcde** under this function gives the amount the respondent would be willing to pay to clean up the near beach if an alternative clean beach were available at a distance of 20 kilometers (20 francs).[14] The mean value for this area is about 115 francs per family per week. The area **jbcde** gives the amount the respondent

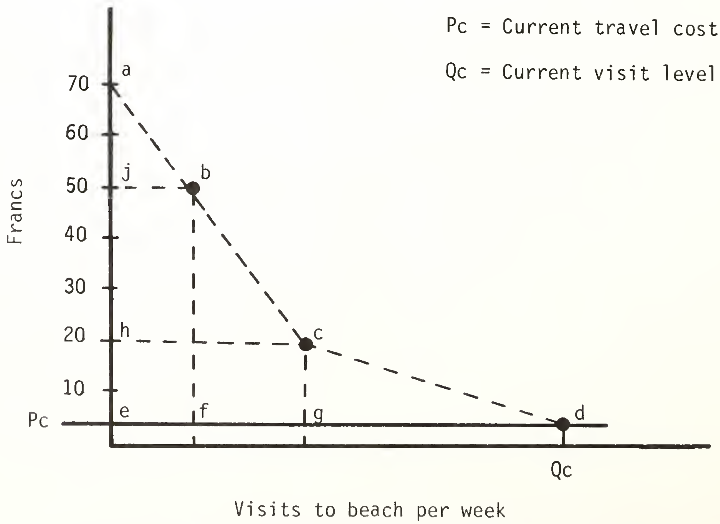

Figure 4–2.—Household Willingness-to-Pay Function for Clean Beaches.

would be willing to pay if an alternative clean beach were available at a distance of 50 kilometers. The mean value for this distance is about 145 francs per family per week. The area **abcde** gives the willingness-to-pay if an alternative clean beach were available 70 kilometers (70 francs) away. The mean value for this distance is about 150 francs per family per week.

Using 162 responses without missing data on the relevant variables, the areas under the "willingness-to-pay" (*WP*) functions were regressed on a number of explanatory variables, namely, the distance the individual had traveled from his home to the area in kilometers (*TRAVEL*); whether or not the beach was regarded as important to the respondent's activities (*BCHIMP*), "1" when regarded as important, "0" when it was not; whether or not the commune in which the beach was located had experienced pollution from the Amoco Cadiz oil spill (*POLLUT*), "1" when it had, "0" when it had not; the respondent's annual income (*INCOME*), francs; and the distance of the accommodations from the beach (*BCHDST*) in kilometers.

The result of this linear regression for *WP*=**abcde** in figure 4–2 was

$$\begin{aligned} WP = {} & \underset{(11.75)}{126} + \underset{(0.18)}{0.21 \times 10^{-4}\, INCOME} \\ & + \underset{(0.43)}{0.20 \times 10^{-1}\, TRAVEL} + \underset{(3.63)}{37\, BCHIMP} \\ & + \underset{(0.25)}{2.4\, POLLUT} - \underset{(-4.43)}{4.4\, BCHDST}. \end{aligned} \tag{4–1}$$

$N = 162$; $AdjR^2 = 0.16$; t-statistics in parentheses.

Only the *BCHIMP* variable and the *BCHDST* variable were significant predictors of *WP*. Families for whom the beach was an important part of their visit had a higher willingness-to-pay, as did families whose accommodations were relatively close to the beaches they visited.

The *WP* values produced from Figure 4–2 are weekly values reflecting multiple trips per week to the beach. Assuming that the alternative beach is 20 kilometers away, and multiplying the mean *WP* value of 115 francs per week associated with that distance by the mean vacation length of 30/7 weeks, yields a mean seasonal *WP* per family of about 490 francs. This amount represents the mean willingness-to-pay of a family for a clean beach. Using the mean family size of 3.8 in the ODES sample yields a mean seasonal *WP* of about 130 francs per visitor. This value represents the estimated loss as a result of the oil spill, to each tourist who did come in 1978.

However, it should be emphasized that the above figure is based on a number of assumptions. In particular, the analysis was premised on the condition that the customary beaches visited by those interviewed looked as in the photographs they were shown of quite oiled beaches. Beaches on the Brittany coast were, in fact, cleaner than the pictures shown in the interviews. Thus, 130 francs would be an overestimate of losses if 20 kilometers is an accurate estimate of how far people would have had to travel to find a clean beach. Lack of data on the geographic distribution of tourists' destinations made it too costly to test the 20 kilometers estimate. It seems like an underestimate, given that 400 kilometers of coastline were affected. It is probable people would have incurred extra travel of more than 20 kilometers to get to an acceptable beach. In addition, some cost-minimizing alternatives, e.g., traveling to another area entirely, were precluded in the context of the question, and the questions were hypothetical. It may be expected that these factors would contribute to a value which was an overestimate.

Willingness-To-Pay Method

The ODES survey provided data for the application of two types of willingness-to-pay analysis. The first involved the willingness-to-pay for insurance; the second involved compensation in terms of extra days paid vacation.

Hypothetical Insurance Purchase. Both theory and practice indicate that people purchase insurance to protect themselves against losses. For example, if a homeowner does not buy fire insurance he runs a small chance of incurring a large loss if a fire occurs, and a large chance of incurring no loss due to fire. Paying for fire insurance converts this lottery with two different possible outcomes into a situation where real income is the same whether there is a fire or not. Income net of a fair insurance premium is called certainty income in the relevant literature on utility in uncertain situations.[15]

Figure 4–3 showing the relationship between a person's income and its utility to him illustrates these concepts. For example, if there is an 80 percent chance of having income of Y_2, and a 20 percent chance of having income of Y_1, the expected income is $\overline{Y}$. The certainty equivalent income is Y^*. It yields a utility level $U(Y^*)$ which is equivalent to the expected utility in the uncertain (lottery) situation, i.e., $0.2U(Y_1) + 0.8U(Y_2)$. The risk premium is $\overline{Y} - Y^*$, the amount willingly paid to avoid the risks of the uncertain situation.

With the advent of oil spills, more uncertainty is introduced into the environment. Tourists and residents now run the risk of incurring losses in satisfaction and/or real income should an oil spill occur. Under the typical assumption that people are averse to risks, they should be willing, in principle, to buy insurance to protect themselves against uncertain losses. In Figure 4–4, M is the real income level of, and $U(M)$ is the associated utility of, a representative tourist if there is no oil spill. Should an oil spill occur, it reduces real income by a loss, L. The expected real income level, considering the probability of spills, is denoted by $\overline{M-L}$, and the expected loss of utility is the difference between $U(M)$ and $U(\overline{M-L})$. By payment of a figurative premium, P, in each period, real income will be reduced to $M-P$. Damages from oil spills, should they occur, will be compensated by the

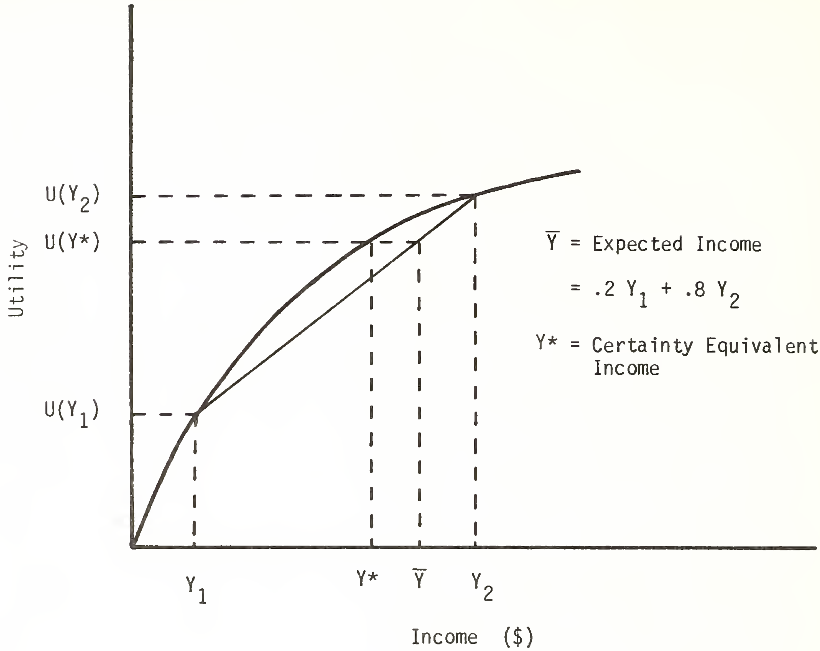

Figure 4–3.—Risk Premium and Certainty Equivalent Income.

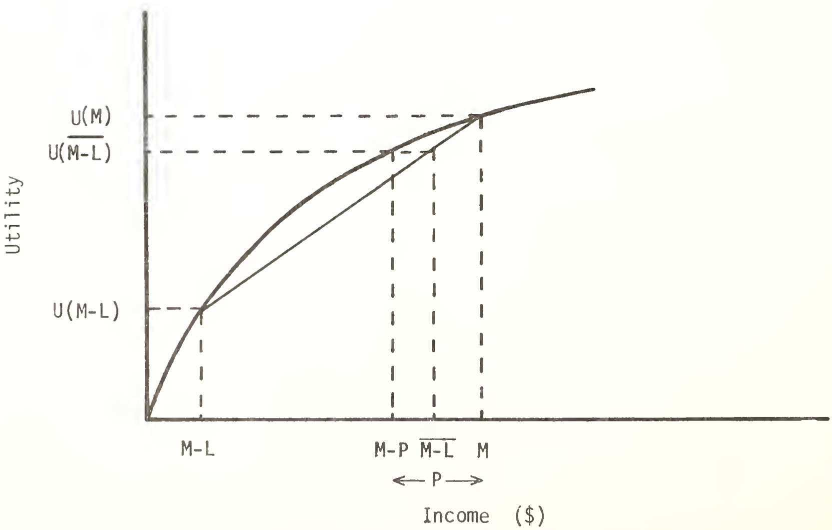

Figure 4–4.—Losses Estimated by Hypothetical Insurance Purchases.

amount of insurance purchased. In a fair situation, the aggregate sum of the premiums paid period after period just equals the total of losses paid out after the infrequent event of an oil spill (neglecting administrative costs). Thus, either the amount of insurance tourists buy, or the premium divided by the probability of loss, is a measure of tourists' expected losses from their point of view.

There are no well-developed insurance markets protecting prospective tourists to Brittany against losses due to an oil spill. However, the concept is not wholly fanciful, because skiers in some French resorts are insured against the prospect of unsatisfactory snow conditions. However, the skiers do not buy the insurance directly, and the French are said to have a negative attitude toward insurance.

The procedure of using questions concerning purchase of insurance to elicit quantitative measures of welfare change shows a good deal of promise.[16] However, the procedure is vulnerable to the generic attacks on hypothetical questions. In addition, there are some who believe that people do not understand probabilities well enough, at least in artificial settings, to reveal behavior consistent with expected maximization.[17]

Because direct observation of oil spill insurance transactions were not available, hypothetical insurance options were offered to the sample of 390 tourists and 198 residents in the ODES survey. Two questions were asked, both based on a specified chance of occurrence of a spill equivalent to that of the Amoco Cadiz of 5 percent. In the first question respondents could purchase as much damage insurance as they wanted by paying a premium equal to 2.5 percent of the insured amount, assuming the government pays the other half of the premium; in the second question they could pay 5 percent of the insured amount, under the assumption of no subsidy by the government.

The second insurance question reflects the fact that the respondents were offered a fair gamble, that is, the *cost* of insurance equaled the product of the amount of insurance weighted by the stated probability of an oil spill of the given magnitude. The conceptual basis for this second question is the compensating variation measure of welfare change. That is, individuals are assumed to have no right to a clean beach and therefore must pay the full cost of insurance to protect themselves.

If, on the other hand, individuals do have the right to a clean beach, then they should not have to pay premiums to insure a damage-free vacation. If they have a partial right, then they should pay partially. The partial-right point of view is reflected in the first question. Thus the conceptual basis for the first insurance question is a mixed compensating, equivalent variation measure of welfare changes because respondents are asked to pay one-half the price of a fair gamble.[18]

Only 23 of 387 tourist respondents, about 6 percent, gave non-zero answers to the first insurance question, in which the premium was 2.5 percent of the insured amount. Three hundred sixty-four respondents would purchase no insurance. The weighted mean amount the tourists were willing to buy was about 310 francs. This amount represented about 10 percent of the mean expenditures of the tourist families on their visits. This amount and the mean family size of 3.8 yield an estimate of about 80 francs per tourist as a measure of the individual loss in welfare as a result of an oil spill comparable to that of the Amoco Cadiz. Responses by tourists to the second insurance question, in which the premium rate was double that in the first question, yielded a weighted mean amount of insurance which would be purchased per family of about 125 francs. This represents about 35 francs per tourist.

The distributions of amounts of insurance which would have been purchased by tourist families in response to the two questions are shown in Table 4–5. It could not be ascertained whether or not the two mean figures can be considered representative, because it was not possible to determine the sign and magnitude of the response bias, if any.

Hypothetical Extra Days Vacation Provided Tourists. Another approach for estimating the loss in satisfaction as a result of the oil spill is to determine how many days of supplemental paid vacation would be required to induce those respondents who visited Brittany in 1978 to visit the beaches in 1979 if they were in the same condition as in 1978 at the same date. This question was posed to the sample of 390 tourists interviewed in the ODES survey in 1979. Forty-three percent of this sample, or 167, had visited the oil spill region in 1978. The distribution of responses is shown in Table 4–6.

As shown in the table, 93 percent—all but eight respondents—said they would have come without receiving compensation of any additional days. Four of the respondents said they would not have come at all. Because these four rejected 20 days of extra paid vacation—the maximum option provided in the question—it was assumed that the opportunity cost for each of these respondents was *at least* as large as the monetary equivalent of 20 days. An amount equivalent to 30 days was assigned to each. The resulting distribution yielded a weighted mean compensation amount per person of about 110 francs, about three-fourths of which was accounted for by the preferences of three of the eight respondents. If these three observations are excluded, the weighted mean compensation amount per person is about 30 francs. Thus, the estimated loss of satisfaction is highly sensitive to the way those who said they would not come at all are treated in the analysis. The lower figure of 30 francs was chosen for comparison with the results of the other methods.

Comment on Willingness-To-Pay Results. It should be emphasized that in interviews in which hypothetical questions are posed, it is typical to encounter extreme answers, and just as typical for the analyst to exclude them from the results, for reasons which are not defen-

Table 4-5.—Willingness-to-Pay for Insurance Against Oil Spills, Tourists Interviewed in Brittany in 1979.

	Insurance Question 1[a]		Insurance Question 2[b]	
	Amount of Insurance Theoretically Purchased, (1978 FR x 10^3)	Number of Respondents	Amount of Insurance Theoretically Purchased, (1978 FR x 10^3)	Number of Respondents
	0	364	0	374
	2	9	1	5
	4	6	2	4
	6	2	3	2
	8	1	4	1
	10	2	5	2
	12	2	6	1
	14	1	10	1
TOTAL	--	387	--	390
Weighted mean amount per family (FR): Question #1, 310; Question #2, 125				

[a] Annual premium equal to 2.5% of insured amount.
[b] Annual premium equal to 5% of insured amount.

sible except on pragmatic grounds. Respondents may give extreme answers because they happen to feel that way. If an individual actually possesses the right to a clean beach, he can refuse to sell it to a private party at any price. But extreme answers simply may reflect a misunderstanding of the question or a misunderstanding of the analyst's implicit frame of reference which the respondent was supposed to adopt in answering the question. As one reviewer pointed out, respondents may not regard an offer of additional vacation days as a plausible option. If so, then they may not answer the question seriously. As questions become more unreal to the respondents, the validity of their responses suffers. However, these uncertainties must remain caveats. The nature of the ODES survey precluded study of motives for extreme answers.

ESTIMATING THE UNIT LOSS TO RESIDENTS OF COASTAL BRITTANY IN 1978

Although many residents of coastal Brittany modified their recreation patterns in 1978 because of the oil spill, specific evidence of what those modifications were, and the losses in satisfaction induced thereby, are virtually nonexistent. Only a rough indication of possible magnitude of loss per family can be derived from the ODES survey, based on responses to the first insurance question.

Of the 198 residents of coastal Brittany in the ODES sample responding to the first insurance question, 178 would purchase no insurance. Only 20, about 10 percent, gave non-zero answers. Four said they would buy more than 7 thousand francs worth of insurance. They were assigned twice the maximum amount of insurance specified, or 14 thousand francs.[19] The distribution of responses is shown in Table 4–7.

The weighted mean amount of insurance the residents were willing to buy was about 580 francs per family. If the amount purchased in the largest category is 7 thousand francs instead of 14 thousand francs, the weighted mean amount is about 440 francs per family. The 580 francs and 440 francs for the residents, in response to the first insurance question, are two estimates of the welfare losses per resident family in the Brittany coast attributable to the Amoco Cadiz oil spill. They are analogous to the 310 francs per family for the tourists, as

Table 4–6.—Extra Days of Paid Vacation to Offset Reduction in Beach Quality, Tourists Interviewed in Brittany in 1979.

Number of Extra Vacation Days	Number of Respondents	Income per Year (FR x 10^3)	Income per Day[a] (FR)	Compensation Income per Respondent[b], (1978 FR)
None	159	--	0	0
2	1	33	90	180
2	1	42	115	230
2	1	108	296	592
6	1	24	66	396
30 (Would Not Come)[c]	1	42	115	3450
30 (Would Not Come)[c]	1	54	148	4440
30 (Would Not Come)[c]	1	54	148	4440
30 (Would Not Come)[c]	1	54	148	4440
TOTAL	167			

Mean compensation income per responding person (FR):

Total sample.................110

Excluding highest three.......30

[a] Annual income divided by 365.
[b] Compensation income = income per day x number of extra paid days of vacation as compensation.
[c] Respondents considered 20 days inadequate; 30 days were assumed.

described previously. Assuming the responses of the sample of the residents were representative of the attitudes of the families residing in the oil-damaged section of the Brittany coast, the unit value obtained in the survey could be applied to the number of resident families to yield an estimate of the losses in satisfaction (social costs) in 1978 to the residents because of the oil spill. Using the 440 francs per family figure and assuming a family size of four, yields an estimated loss of 110 francs per resident.

The 198 residents responding represent a little less than one-tenth of one percent of the estimated 237 thousand residents in the coastal zone in Finistere and Cotes-du-Nord, (Bonnieux, et al., 1980). Thus, the sample is very small, and there are no data on which to base any estimate of the direction and extent of bias in the responses, if any. Given the range in the estimates of unit loss to tourists who did come in 1978, from 3 francs per person to 130 francs per person, 110 francs per resident seems reasonable as an upper limit of the welfare loss to a resident as a result of the spill. The lower limit is assumed to be zero.

RECAPITULATION, ESTIMATED LOSSES, AND DISTRIBUTION OF LOSSES

Recapitulation

Three groups of individuals incurred losses in satisfaction not measured directly by market prices as a result of the oil spill in 1978: (1) tourists who had planned to go to the Brittany coast but changed their plans and did not go, but went elsewhere or stayed at home; (2) tourists who came but modified their activities; and (3) residents of the Brittany coast who modified their recreational patterns. These losses were incurred in 1978. No losses in satisfaction are assumed to have occurred in subsequent years. The magnitude of the downward bias, if any, in estimated losses as a result of this assumption is not known.

With respect to the first group, there are no carefully recorded data of the number of tourists who did not come to Brittany in 1978. By putting bits and pieces of information together, it was estimated that between 215 thousand and 277 thousand tourists stayed away

Table 4-7.—Willingness-to-Pay for Insurance Against Oil Spills, Residents of Coastal Brittany Interviewed in 1979.

Amount of Insurance Theoretically Purchased, (FR x 10^3)	Number of Respondents
0	178
1	4
2	3
3	1
4	1
5	3
6	1
7	3
14	4
TOTAL	198
Weighted mean insurance purchased per family (FR):	
With maximum amount of insurance being 14,000 francs	580
With maximum amount of insurance being 7,000 francs	440

from the shoreline of Brittany in 1978. The midpoint of this range, about 245 thousand, represents a loss of about 11 percent, given the estimated total of tourists expected in Brittany in 1978 of about 2.32 million. It would have been prohibitively expensive to identify the origins of those in this group. Because Germany is the origin of the largest fraction of foreign tourists (at least 20 percent), German tour operators were selected as proxies for the tourists. The tour operators were asked how much extra expenditures German tourists chose to make to have a vacation as pleasant as they would have had if they had not canceled their trip to Brittany. On average, German tourists were estimated to have been willing to pay an extra 190 francs each to have the same quality vacation.

With respect to the second group, two basic analytical methods were used to derive estimates of the loss per visitor: (1) travel cost; and (2) willingness-to-pay or willingness-to-sell in relation to various hypothetical conditions posed. The basic idea of the travel cost method is that individuals living a greater distance from a beach visit the beach less frequently—because of higher travel costs—than those living closer to the beach. Differences in the implicit price (cost) of access can be matched with different rates of attendance to yield a demand curve for beaches. The value of a beach, computed from the demand curve, is the difference between what visitors actually pay and their maximum willingness-to-pay as estimated by the area under the demand curve. Should an oil spill occur, one would expect that the number of visits to a beach in Brittany by people from each region of origin would decline. Tourists would substitute higher cost alternative activities for some or all of their customary beach activities. Analysis using visitation data for 1978 and 1979 from the INSEE survey indicated only a small difference in rates of visitation between the two years. The difference yielded an estimated loss of about 3 francs per tourist, based on actual distances French tourists to Brittany had traveled.

Hypothetical travel cost analysis was also used, based on interviews of a small sample of tourists in the ODES survey. Tourists were shown pictures of beaches as they appeared before any cleanup took place. They were asked how frequently they would choose a clean beach if it were 0, 20, or 50 kilometers away, and their usual beach looked like those pictured. Analysis based on their responses indicated that the mean willingness-to-pay was about 130 francs per visitor for the season if the clean beaches were 20 kilometers away. But this analysis was premised on the condition that their customary beaches looked like the photographs of highly oiled beaches. Beaches on the Brittany coast were, in fact, cleaner than the pictures shown in the questionnaire. Thus 130 francs would be an *overestimate* of losses if 20 kilome-

ters is an accurate estimate of how far people would have to travel to find a clean beach. Lack of data on the geographic distribution of tourists' destinations made it too costly to test the 20 kilometers estimate. It seems like an underestimate, given that about 400 kilometers of coastline were affected to a greater or lesser extent by the oil spill. It is probable people would have incurred extra travel of more than 20 kilometers. Whether or not the likely longer travel distance would compensate for the overestimate of extent of oil on beaches in the pictures is not known.

The willingness-to-pay (sell) method was applied by asking tourists a number of hypothetical questions designed to obtain indirectly monetary valuation of their losses in satisfaction as a result of the oil spill. Tourists were asked how much insurance against oil spill damages during their vacations they would purchase at alternative costs of the insurance. Losses estimated in this fashion ranged from about 35 to about 80 francs per tourist, depending on the level of premiums they would have had to pay. The lower figure is equivalent to about 4 percent of the sampled respondents' expenditures for a vacation. Tourists were also asked how many extra days of paid vacation they would demand in return for vacationing in an oil spill area. The mean response was equivalent to about 30 francs per tourist, depending on how extreme answers were treated.

The only evidence concerning losses to residents was obtained by asking a sample of residents of the coastal area how much insurance they would purchase against a specified probability of the occurrence of another oil spill comparable to that of the Amoco Cadiz. The mean response was about 110 francs per coastal resident.

Estimated Losses

The unit losses summarized in the above were applied to the respective, relevant populations in the three categories: (1) tourists who did not come in 1978; (2) tourists who did come in 1978 despite the oil spill; and (3) residents of the affected coastal area of Brittany. The results are shown in Table 4–8 in francs and dollars.

What is one to make of the estimates in Table 4–8? They are not solid, robust estimates, obtained from data which have proved to be highly accurate and reliable because of supporting corroborative data and tests. It is particularly important to emphasize two limitations. First, the unit loss estimates are based on quite small samples. Second, except for the INSEE data used in the first travel cost analysis, the loss estimates are based on responses to questions concerning willingness-to-pay under hypothetical conditions, questions to which French and other Europeans are unaccustomed to respond. Nevertheless, the estimates provide some feel for the order of magnitude of potential damages.

The estimated losses to recreationists are about 55–340 million 1978 francs, about 15–80 million dollars, with various values in between these two. The range is a function of (1) which method is used for estimating the unit loss to tourists who did come; and (2) which assumption is adopted about the unit loss to Brittany coastal residents. It would be surprising if the losses were more than about 340 million 1978 francs, about 80 million dollars, or less than about 55 million 1978 francs, about 15 million dollars.[20]

Distribution of Losses

To distribute the foregoing losses among regions—to Brittany, within France but outside Brittany, and outside France (the rest of the world)—is an exercise in making reasonable assumptions, because neither the origins of the tourists who did not come, nor the origins of those who did come, are known. The basis for the allocation among origins starts with Table 4–2, which showed the estimated reduction in tourists in coastal Brittany in 1978 by type of accommodation.

The following assumptions were made about those tourists who did *not* come during the July-August period of 1978. First, on the basis of a study by INSEE (1979), foreigners were estimated to constitute about 80 percent of the reduction of 14 thousand tourists in hotels, or about 11 thousand. Second, foreigners were estimated to account for about 53 percent of the reduction of about 101 thousand tourists in camping accommodations, or about 53 thousand. Third, foreigners were estimated to account for about 25 percent of the estimated 69 thousand who stayed in "other" accommodations, given the fact that foreigners represent only a small proportion of those renting second homes. Assuming all of the 25 percent in this last type of accommodation did not come yielded about 17 thousand. Thus, the estimated number of foreigners who did not come during the summer season equaled about 81 thousand. Using the previously indicated estimate that three-fourths of the annual number of tourists come in the summer yielded an estimated 110 thousand foreigners who did not come in the entire year of 1978. Fourth, the remainder of those who did not come—the total of 245 thousand minus the 110 thousand, or 135 thousand—was apportioned 90 percent to France outside of Brittany and 10 percent to Brittany, or about 121 thousand and about 14 thousand, respectively. The number should be larger, although one does not know how much larger, for those from France outside Brittany than for those from Brittany, because the former had poorer information and more substitutes.

With respect to those tourists who *did* come in 1978, it was estimated that 20 percent of those who did come during the year and camped or stayed in hotels were foreigners, about 186 thousand. It was then assumed that 5 percent, or about 57 thousand, of the remaining tourists were foreigners. The result was an estimated total of about 243 thousand tourists to have come from outside France. Applying the same asumption as above with respect to the distribution of French tourists, i.e., 90 percent from France outside Brittany and 10 percent

Table 4-8.—Estimated Losses in Satisfaction of Tourists to, and Residents of, the Brittany Coastal Area Affected by the Amoco Cadiz Oil Spill.

Category of Individuals Affected	Estimated Number, 10^3	Method for Estimating Unit Loss	Unit Loss (FR)	Estimated Losses (1978 FR x 10^6)
Tourists who did not come in 1978	245	Interviews with German tour operators	190	46.6 (11)[a]
Tourists who came in 1978 but incurred losses in satisfaction	2,070	Travel cost: INSEE data	3	6.2 (1.5)
		Travel cost: ODES data	130	269 (64)
	2,070	Hypothetical insurance purchased	80	166 (40)
			35	72.4 (17)
	2,070	Extra days paid vacation	30	62.1 (15)
Coastal residents[b]	237	--	0	0
		Hypothetical insurance purchased	110	26.1 (6.2)
TOTAL LOSSES Minimum (lowest) estimate, 10^6 1978 FR[c]				53 (13)
Maximum (highest) estimate, 10^6 1978 FR[d]				342 (82)

[a] Figures in parentheses are dollars x 10^6, based on 1978 exchange rate of 4.18 francs per dollar.
[b] Population of littoral zone in Finistere plus Cotes-du-Nord (Bonnieux, et al., 1980, Table 1).
[c] Minimum = Sum of minimum values in the three categories of the column.
[d] Maximum = Sum of maximum values in the three categories of the column.

from Brittany, to the remaining 1.83 million yielded about 1.64 million from outside Brittany and about 0.18 million from Brittany. The results of the above calculations are shown in Table 4–9.

Given (1) the estimated origins of the tourists who did not come and (2) the estimated origins of the tourists who did come and (3) assigning all monetary losses to coastal residents as costs to Brittany, the estimated distribution of losses is derived by multiplying the number of individuals in each category by the relevant unit values, e.g., 190 francs per person for those who did not come, 3–130 francs for those who did come, and zero or 110 francs for residents. The results are shown in francs and dollars in Table 4–10. The estimated minimum and maximum losses and their distributions are shown in francs and dollars in Table 4–11A, and in percentages in Table 4–11B.

The distribution of losses is sensitive to the unit losses estimated for those who did come in 1978 and for the coastal residents, assuming that the unit loss for any tourist who did not come is the same, regardless of origin. If coastal residents of Brittany are assumed to have incurred no losses, then—as the estimated unit loss to those tourists who came increases from 3 francs to 130 francs—the proportion of the total losses incurred outside France decreases from about 41 percent to about

Table 4-9.—Estimated Geographic Origins of Tourists Who Did Not Come and Did Come to the Brittany Coast in 1978.

Origins	Number of Tourists Who Did Not Come (x 10^6)	Number of Tourists Who Did Come (x 10^6)	Total (x 10^6)
Outside France	0.110	0.243	0.353
France outside Brittany	0.121	1.644	1.765
Brittany	0.014	0.183	0.194
TOTALS	0.245	2.070	2.315 (rounded to 2.32)

Table 4-10.—Estimated Geographic Distribution of 1978 Recreation Losses, by Method of Estimation.

	Method of Estimating Unit Loss	Estimated Unit Loss, francs	Losses Incurred (1978 FR x 10^6)[a]			
			Outside France	France Outside Brittany	Brittany	Total Losses
Tourists who did not come	Interviews with German tour operators	190	20.9 (5.0)	23.0 (5.5)	2.7 (0.6)	46.6 (11.1)
Tourists who did come	Travel cost INSEE data	3	0.7 (0.2)	4.9 (1.2)	0.6 (0.1)	6.2 (1.5)
	ODES data	130	31.6 (7.6)	213.7 (51.1)	23.8 (5.7)	269 (64.4)
	Hypothetical insurance purchased	80	19.4 (4.6)	131.5 (13.8)	14.6 (1.5)	166 (39.6)
		35	8.5 (2.0)	57.5 (13.8)	6.4 (1.5)	72.4 (17.3)
	Extra days vacation	30	7.3 (1.7)	49.3 (11.8)	5.5 (1.3)	62.1 14.8)
Coastal residents	- -	0	--	--	0	0
	Hypothetical insurance purchased	110	--	--	26.1 (6.2)	26.1 (6.2)

[a] At 4.18 francs per dollar; dollars (x 10^6) in parentheses.

17 percent, the proportion incurred by France outside Brittany increases from about 53 percent to about 75 percent, and the proportion incurred by Brittany increases from about 6 percent to about 8 percent. If coastal residents of Brittany are assumed to have incurred a loss of 110 francs per resident, then as the estimated unit loss to those tourists who came increases from 3 francs to 130 francs, the proportion of the total losses incurred outside France decreases from about 27 percent to about 15 percent; for France outside Brittany the proportion increases from about 35 percent to about 69 percent; and for Brittany the proportion decreases from about 37 percent to about 15 percent.

Table 4-11.—Estimated Geographic Distribution of Total 1978 Recreation Losses.

4-11a. Losses by geographic area (1978 FR x 10^6)[a]

Geographic area incurring losses	Assuming 0 francs loss per resident		Assuming 110 francs loss per resident	
	Minimum[b]	Maximum[c]	Minimum[b]	Maximum[c]
Outside France	21.6 (5.2)	52.5 (12.6)	21.6 (5.2)	52.5 (12.6)
France outside Brittany	27.9 (6.7)	237 (56.6)	27.9 (6.7)	237 (56.6)
Brittany	3.3 (0.8)	26.5 (6.3)	29.4 (7.0)	52.6 (12.6)
Totals	53 (13)	316 (76)	79 (19)	342 (82)

4-11b. Losses by geographic area, percentage of total losses

Geographic area incurring losses	Assuming 0 francs loss per resident		Assuming 110 francs loss per resident	
	Minimum[b]	Maximum[c]	Minimum[b]	Maximum[c]
Outside France	41	17	27	15
France outside Brittany	53	75	35	69
Brittany	6	8	37	15
Totals	100	100	99	99

[a] At 4.18 francs per dollar; 1978 dollars (x 10^6) in parentheses.
[b] Minimum = sum of minimum values in each category in each column of table 4-10.
[c] Maximum = sum of maximum values in each category in each column of table 4-10.

NOTES

[1] Limiting the analysis to tourists, as defined, ignores whatever non-market-valued social costs were imposed on households spending less time in Brittany. Also ignored are benefits which might have accrued to visitors who were drawn to the beaches of Brittany to see the oil spill and the cleanup operations.

[2] Bonnieux, et al. (1980) reported a vacation level of 70 million nights for 1978. At the national average of 26 days for a vacation, that number would have represented about 2.7 million visitors. This number is for all of Brittany. About 85 percent of the visitors to Brittany are estimated to go to, and stay in, the coastal zone. Combining these two estimates yields about 2.3 million visitors.

The estimate by Bonnieux, et al. became available after this analysis was made. The basis for their estimate is not available.

[3] Campsite occupancy rate was said to be about 61 percent in 1978, according to the Institut National de la Statistique et des Etudes Economiques (1979). However, occupancy rates for other years on a comparable basis are not available.

[4] All subsequent references to Germany mean the Federal Republic of Germany.

[5] For example, see Comite Departmental de Developpement et d'Amenagement du Finistere (1979).

[6] The interviews were conducted in German by Cathy Carruthers, a graduate student at the University of Washington, and took place in Germany during June and July of 1979.

[7] It was assumed that deposits were included. If this assumption is incorrect, losses are underestimated.

[8] For discussion of the basic outline of the travel-cost method see Clawson (1959) and Clawson and Knetsch (1969). Subsequent applications became more sophisticated in terms of the way in which they accounted for the effects of substitute sites. See Burt and Brewer (1971), Cicchetti, Fisher and Smith (1976), and Cesario and Knetsch (1976). Excellent discussions of the state of the art in applying the method are found in Dwyer, Kelly and Bowes (1977) and in Freeman (1979).

[9] INSEE is analogous to the U.S. Bureau of the Census.

[10] Corse was excluded, because there were no recorded visitors from Corse.

[11] For discussions of the role of time costs see McConnell (1975), Cesario (1976), and Wilman (1980).

[12] Two simplifications were used in calculating the areas. One, because of the logarithmic form, the demand curves approach the price axis only asymptotically. Hence, the slope of each curve was assumed constant for visit levels of less than 100 per 107 population. Two, because the demand curves are non-linear, they were approximated by linear segments over price intervals of 100 francs.

[13] The most difficult task was to prepare the willingness-to-pay (WP) and willingness-to-sell (WS) questions. No one outside the United States was found who believed that people in France could or would respond usefully to hypothetical WP or WS questions. In fact, the responses to queries on this point varied from embarassed laughing to incredulity to ridicule. Many questions were developed in the original pilot survey and many helpful recommendations were contributed by others, including J. Dirlam, N. Meade, and B. Deniaux. Those questions regarded by "native informants" as least offensive were then put in acceptable wording by A. Somia of ODES.

The method of using hypothetical WP questions was first developed in the U.S. by Davis (1964) and subsequently revised by Mathews and Brown (1967), Hammack and Brown (1974), and others.

The questionnaire form with the results summarized can be obtained from Gardner M. Brown, Jr., Institute for Economic Research, University of Washington, Seattle, Washington, 98195. A short summary of the results of the survey is contained in the Appendix to this chapter.

[14] Strictly speaking this area represents the willingness-to-pay measure of the consumer surplus lost in the event of an oil spill when the nearest clean beach is 20 kilometers away.

[15] See Kenny and Raiffa (1976).

[16] Use of the approach was suggested by Professor Roger Noll of the California Institute of Technology.

[17] See Gruenther and Plott (1979).

[18] It should be emphasized that no claim is made about who in fact has or should have the right to clean beaches. Rather, what is being done is only to locate the right, i.e., specify the initial endowment consistent with each measure of welfare change. The problem with offering insurance at better than fair prices is that it invites cheating.

[19] Two of the four respondents reported their income at an average of 30,000 francs. The assumption that those who would have bought the most insurance were those who lost at least half their annual income from the oil spill, led to assigning each of the four a purchase of 14,000 francs of insurance.

[20] Using the Bonnieux, et al. (1980) estimates of the number of tourists who did not, and did, come in 1978, 0.38 million and 1.94 million, respectively, and the same unit losses, yields a range of about 75 million 1978 francs to about 350 million 1978 francs. The differences between the estimates are substantially less than the accuracies of the estimates.

REFERENCES

Bonnieux, F., P. Dauce, and P. Rainelli, 1980: *Impact Socio-Economique de la Maree Noire Provenant de l'Amoco Cadiz.* Institut National de la Recherche Agronomique, Rennes, France, 248 pp.

Bonnieux, F., and P. Rainelli, 1980: Le Tourisme sur le littoral Breton: son importance et son recul en 1978. Institut National de la Statistique et des Etudes Economiques, Service d'Etudes de la Direction Regionale de Rennes, Octant No. 2, Rennes, France.

Burt, O.R., and Brewer, D., 1971: Estimation of net social benefits from outdoor recreation. *Econometrica*, 39, 813–827.

Cesario, F.J., and J.L. Knetsch, 1976: A recreation site demand and benefit estimation model. *Regional Studies*, 10, 97–104.

Cesario, F.J., 1976: Value of time in recreation benefit studies. *Land Economics*, 52, 37–44.

Cicchetti, C.J., A.C. Fisher, and V.K. Smith, 1976: An economic evaluation of a generalized consumer's surplus measure: the Mineral King controversy. *Econometrica*, 44, 1259–1276.

Clawson, M., 1959: *Methods of Determining the Demand for and Value of Outdoor Recreation.* Reprint No. 10, Resources for the Future, Washington, D.C.

Clawson, M., and J.L. Knetsch, 1969: *Economics of Outdoor Recreation.* Baltimore, Johns Hopkins University Press.

Comite Departmental de Developpement et d'Amenagement du Finistere, 1979: Note de Synthese sur les Incidences Economiques de la Catastrophe de l'Amoco Cadiz, Quimper, France (January).

Cormier, H., and R. LeMoal, 1980: La saison estivale 1979 en Bretagne, Institut National de la Statistique et des Etudes Economiques, Service d'Etudes de la Direction Regionale de Rennes, Octant No. 1, Rennes, France (February).

Davis, Robert K., 1964: The value of big game hunting in a private forest, in *Transactions of the Twenty-Ninth North American Wildlife and Natural Resources Conference.* Washington, D.C.: Wildlife Management Institute, 393–403.

Dwyer, J.F., J.R. Kelly, and M.D. Bowes, 1977: *Improved Procedures for Valuation of the Contribution of Recreation to National Economic Development.* University of Illinois at Urbana-Champaign, Water Resources Center.

Freeman, A.M., 1979: *The Benefits of Environmental Improvements: Theory and Practice.* Baltimore, Johns Hopkins University Press.

Gruenther, P., and C. Plott, 1979: Economic theory of choice and the preference reversal phenomenon. *American Economic Review*, 69, 623–638.

Hammack, J., and G.M. Brown, Jr., 1974: *Waterfowl and Wetlands: Toward Bioeconomic Analysis.* Baltimore, Johns Hopkins University Press.

Institut National de la Statistique et des Etudes Economiques (INSEE), 1979: *La Saison Hoteliere en Bretagne,* Service d'Etudes

de la Direction Regionale de Rennes, Octant No. 1, Rennes, France (February).

Kenny, R., and H. Raiffa, 1976: *Decisions with Multiple Objectives: Preferences and Value Tradeoffs*. New York, John Wiley.

Mathews, S.B., and G.M. Brown, Jr., 1970: *Economic Evaluation of the 1967 Sport Salmon Fisheries of Washington.* Technical Report No. 2, Olympia, Washington, Washington Department of Fisheries.

McConnell, K.E., 1975: Some problems in estimating the demand for outdoor recreation. *American Journal of Agricultural Economics,* 57, 330–334.

Wilman, E.A., 1980: The value of time in recreation benefit studies. *Journal of Environmental Economics and Management,* 7, 3, 272–286.

Appendix

SUMMARY OF RESULTS OF ODES 1979 SURVEY OF TOURISTS AND RESIDENTS

Gardner M. Brown, Jr.

In July and August of 1979 ODES conducted a survey of 390 tourists and 198 residents of Brittany. A variety of questions was used to probe attitudes, expectations, perceptions, willingness-to-pay, losses, and changes in behavior. The tourists sampled were those who had taken at least one other vacation in Brittany during the past three years.

CHANGES IN TOURISTS' PLANS

Sixty-six percent of the tourists in the sample had visited Brittany in 1978; 74 percent and 70 percent reported having visited Brittany in 1976 and 1977, respectively. However, out of the entire sample of tourists, only three individuals (about 1 percent) reported they did not go to Brittany in 1978 because of the spill. Two of these vacationed elsewhere in France and the third vacationed in another country. Another four reported that they shifted the locations of their vacations to other places in Brittany, away from the polluted north coast. Hence, changes in travel plans directly attributed to the Amoco Cadiz oil spill occurred for about 2 percent of those interviewed. Probably this is an underestimate, because those who avoided the Brittany beaches in 1978 may have continued to do so in 1979; hence, they would be underrepresented in the sample. No method exists to determine the magnitude of the bias. Some proportion of the reduction in visitation in 1978 in comparison with the two previous years could have been because of the bad weather in 1978, as well as unvocalized avoidance of the spill.

CHANGES IN TOURISTS' SATISFACTIONS

Of those who did visit the northern Brittany coast in 1978 and 1979, 23 percent reported observing some signs of pollution in 1978, and 20 percent said that the spill had made their vacation less agreeable. However, only 4 percent said they were dissatisfied with their vacations and would not return to the same beaches this year if the beaches were in the same state as the year before.

TOURISTS' ACTIVITIES AND EXPENDITURES

Families in the sample visited the beach an average of seven times a week and stayed 3 to 4 hours per day. A linear regression of beach visits on age, family size, income, and other factors thought to be of possible importance yielded significant coefficients for only two variables; the distance families had traveled to get to the Brittany coast and the closeness of their accommodations to the beach.

Expenditures on such items as food, entertainment, and local transportation averaged about 710 francs per week per family. Regression analysis indicated that the major variables affecting expenditures were income, family size, type of accommodation, and duration of stay. In particular, the amount of time spent at the beach did not appear to have any significant effect on expenditures. The correlation holds whether or not expenditures for travel and accommodation are included. The practical consequence of this result is that if the quality of beaches in 1979 affected beach-related activities, it did not affect the levels of expenditures of those tourists who did visit Brittany in 1979. Relative to the previous year, 1979 expenditures were reported to have increased an average of about 10 percent, a finding consistent with the general level of inflation in France at that time and not indicating any major shifts because of the oil spill.

TOURISTS' ATTITUDES WITH RESPECT TO THE OIL SPILL

On the whole, the tourists expressed opinions that the Amoco Cadiz oil spill was a significant disaster, worse than the recent Corsican forest fire, the drought in 1976, and the student uprising in May 1968, and only slightly less serious than the construction of a nuclear reactor close to their homes. Interestingly, tourists felt it was primarily the residents rather than themselves who had been harmed. Strongly supported was the view that with sufficient effort, the possibility of future damages could be largely avoided. The average

expected probability of another major oil spill was 3.5 times per 20 years, although the modal answer—38 percent of the sample size—was the maximum answer permitted, i.e., "5 times or more in the next 20 years." One source said that there had been four spills in the past 11 years. However, not all of these qualify as major spills. Thus it is difficult to conclude whether tourists believe that more or fewer oil spills will occur in the future (Bridgman, 1978).

RESIDENTS' ATTITUDES WITH RESPECT TO THE OIL SPILL

Residents rated the Amoco Cadiz oil spill slightly less serious relative to the above-mentioned fire, drought, and student uprising events, and the nuclear power plant siting problem, than did tourists. They also considered a recurrence of the spill to be a little less likely, i.e., 3.0 vs. 3.5 times in 20 years. Sixty-five percent of the respondents felt the media had paid too much attention to the spill, whereas 22 percent felt the media had paid too little attention. In particular, 48 percent thought that the appearance of the coast or the extent of environmental damage had been exaggerated. On the other hand, 8 percent thought that the ecological impact had been underestimated, and 8 percent believed that the economic losses had been understated.

DAMAGE TO RESIDENTS

Thirty-three percent of the residents interviewed stated that their incomes had declined because of the spill. The average loss of those who reported a loss was 27.5 percent of annual income. The loss spread across the complete sample amounted to about 8 percent of annual income. Fourteen percent of those interviewed had submitted a claim for government indemnities. However, only 8 percent had been awarded full or partial compensation.

With regard to quality of life or non-monetary damages, 25 percent reported negative effects, primarily the inability to go to the beach or to go fishing.

COMPARISON OF BEACHES IN AND OUT OF OIL SPILL REGION

An attempt was made to determine the differential impact of the spill by sampling tourists and residents from areas that had and had not been touched by oil from Amoco Cadiz. One hundred and thirty of the 390 tourists, and 11 of the 198 residents, were from non-polluted beaches.

The characteristics of the tourists who had visited non-polluted beaches generally were very similar to the characteristics of those who had visited polluted beaches. In particular, there was virtually no difference in the frequency of visits to the beach or the number of hours spent there. This is perhaps not surprising, because the effects of the spill were unnoticeable to the casual observer. What was different were the attitudes of these two groups toward the spill. Those visiting beaches outside the spill region saw a recurrence of a spill as more likely, i.e., 4.2 vs. 3.2 times in 20 years, believed the spill was more serious, and believed it was relatively more damaging to inhabitants than tourists.

The small number of residents sampled from oil-free beaches, 11 individuals, prevents generalization. However, it is interesting to note that they were more likely to report that the Amoco Cadiz oil spill adversely affected their quality of life than were those living in oil spill areas, 46 percent vs. 24 percent, and also did not think that the media had exaggerated the impact. However, they viewed the accident as less severe relative to the other events cited above.

SUMMARY

The survey indicated that both tourists and residents were disturbed by the Amoco Cadiz oil spill and felt that it had some significant adverse effects, yet revealed little in the way of actual behavioral changes that could be used to measure these effects in monetary terms. Only 4 percent of the tourists reported changes in plans or major dissatisfaction with their vacations due directly to the spill.

The possibility that perceived damages exceeded those actually suffered is suggested by the findings that the perceived seriousness and likelihood of recurrence of the oil spill is least for residents, moderate for tourists within the spill area, and greatest for tourists at the non-polluted beaches. That is, perceived damages seem to be inversely related to the individual's access to first-hand information through his or her own experience. This is consistent with the position expressed by the majority of the residents that the media exaggerated the impact of the Amoco Cadiz oil spill.

Because the flow of tourists into the region is dependent upon perceptions which may not have been accurate, caution must be used in attributing losses in the tourism industry directly to pollution from the oil spill when misinformation may have played a significant role in discouraging tourists. The accounts in newspaper travel sections remarking how clean the beaches were and the upsurge in visitors in the latter half of the season are relevant in this regard.

REFERENCE

James Bridgman, 1978: How it happened. *Neptune*, 2 (April) as reprinted in *Oceans*, 11, 4, p. 58.

Chapter 5

THE TOURIST INDUSTRY

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INTRODUCTION

The Brittany shoreline is second only to the French Riviera as an important summer resort area in France. The beaches of Brittany attract visitors from throughout the nation, especially from western France, and from several European countries. The negative publicity following the Amoco Cadiz oil spill had a major impact on perceptions of damage to the beaches of the region. For example, interviews with German tour operators revealed that the unfavorable publicity following the oil spill led to cancellations of vacation plans, not only in the zone affected by the spill but also in coastal areas of the region not affected by the the spill, as was described in Chapter 4. From all accounts, the oil spill had an impact on tourism in Brittany in 1978, especially during the early part of the vacation season, although poor weather also may have been a factor explaining reported declines in tourism during 1978.

A decline in tourism causes economic losses to the amalgam of hotels, guest quarters, campgrounds, restaurants, and other establishments that cater in whole or in part to tourists, and to some extent to residents engaged in similar recreational activities. This amalgam is collectively referred to as the *tourist industry*. The focus of this chapter is the estimation of the economic losses to the tourist industry in Brittany as a result of the oil spill.[1]

Figure 5–1 depicts equilibrium in the Brittany tourism market. The normal demand curve, **D**, shifted to the left to **D′** as a consequence of the oil spill. The short-run marginal cost curve, **MC**, is assumed to be relatively inelastic as capacity is approached, reflecting both limited alternative uses for the inputs and rising marginal costs.

Losses in the tourism market consist of two categories: losses to the tourists themselves, including resident recreationists, discussed in the preceding chapter; and losses to the tourist industry. The former losses are approximated by **cdab**, the decline in consumers' surplus; the latter by $\mathbf{cd}Q_0Q_1$. In the short-run, when a single oil spill is viewed in isolation, losses to the tourist industry of the affected region would occur to the extent that resources normally used by the industry, but left idle by the decline in tourism, were unable to find employ-

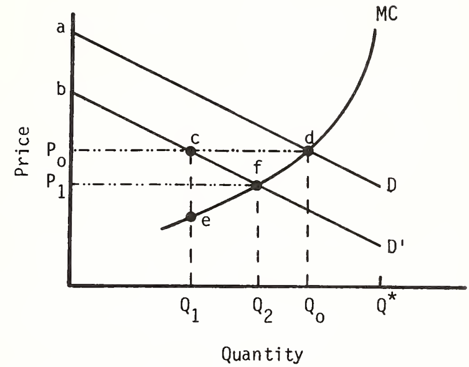

Figure 5–1.—Equilibrium in the Tourist Market in Brittany.

ment at the same compensation. Such losses would occur, for example, when employees are temporarily made idle or when hotels, restaurants, and other facilities are utilized less as a result of the spill.[2]

No evidence was found that indicated that prices of the goods and services provided by the tourist industry fell following the oil spill. For example, 1978 room rates for Brittany hotels were set prior to the oil spill, and were not changed. Thus, the apparent supply curve is represented by the horizontal line $P_0\mathbf{cd}$ in Figure 5–1. The effect of the reduced demand because of the spill, with prices fixed in the short-run, is to reduce the quantity demanded from Q_0 to Q_1. If prices were flexible, the price would drop to P_1 and the equilibrium quantity demanded would decrease from Q_0 to Q_2.

The loss in total revenue to the industry is measured by the area $\mathbf{cd}Q_0Q_1$. This represents an economic cost only if the inputs that were not used in the tourist industry in Brittany in 1978 had no alternative uses either in other economic activities or at a later point in time in the tourist industry. Certainly the flour, gasoline, wine, and film not used directly or indirectly by tourists who stayed away from Brittany in 1978 would all be used in alternative activities. Less clear is the situation for employees of the tourist industry in Brittany whose

services were not needed. The services of labor are not storable, and workers may not be highly mobile in the short-run. Did maids, waiters and waitresses, and clerks made idle by the oil spill find other work? Did individuals who pumped gas part-time find other jobs? These questions are difficult to answer but must be considered in estimating economic losses to the tourist industry. Referring again to Figure 5–1, when the short-run marginal costs, edQ_0Q_1, that were avoided are netted out, the economic cost of the spill to the tourist industry of the region is reduced to **cdfe**.[3]

The losses to the tourist industry described above refer to losses realized within the region directly affected by the oil spill. If a global view of the tourist industry is adopted, the decline in tourism in Brittany was probably accompanied by increases elsewhere as tourists visited their second-choice destinations. Thus, losses to the tourist industry in Brittany were probably balanced by gains to the industry in other regions of France, in other countries, or both.

One last point should also be kept in mind. Not all of the consequences of the spill were harmful to the tourist industry. During the initial weeks following the spill, journalists and reporters from around the world converged on Brittany. Thousands of cleanup workers and at least hundreds, if not thousands, of curious onlookers spent extended periods in Brittany. All of these required services provided by the tourist industry. Losses to the tourist industry should be estimated net of any of these beneficial effects.

CHARACTERISTICS OF THE TOURIST INDUSTRY IN BRITTANY

As indicated in the introduction, Brittany is one of the most popular summer vacation areas in France. During the summer months of July and August of 1979, an estimated 1.74 million visitors spent 41.6 million vacation-days in the region (Cormier and Tessier, 1980). For the entire year of 1979, 2.32 million visitors were estimated to have come to Brittany. Of the four departments in Brittany, Finistere was the most popular vacation area, accounting for almost 40 percent of the summer visitors to the Brittany shore, as shown in Table 5–1. Finistere and Cotes-du-Nord together accounted for 60 percent of all summer visitors to the beaches of the region in 1979.

Most summer visitors to Brittany stayed in second homes or rooms in homes, or in tents and caravans. These categories accounted for about 85 percent of summer accommodations used. In 1979, only 8 percent of the visitors stayed in hotels.

The amount spent by a household during a visit and the length of the visit varied with the type of accommodation, as shown in Table 5–2. In July and August of 1979, the average expenditure per household per visit ranged from about 2.3 thousand francs to about 5.4 thousand francs; the average length of visit ranged from 23 days to 31 days.

About 147 thousand persons were employed in eight tourism-related industries in Brittany in 1975, the last year for which census data were available when this analysis was made. Table 5–3 shows the number of employees by industry and department. About 75 thousand, or 51 percent of the total for Brittany, were employed in Finistere and Cotes-du-Nord.

Employment in the tourism-related industries shown in Table 5–3 accounted for about 15 percent of total employment in Brittany in 1975, and accounted for about 16, 14, 14, and 15 percent of total employment in Finistere, Cotes-du-Nord, Ille-et-Vilaine, and Morbihan, respectively. The industries providing the largest sources of tourism-related employment were Retail Non-Food Trade; Hotels, Cafes, and Restaurants; Wholesale Food Trade; and Retail Food Trade. Employ-

Table 5–1.—Estimated Number of Summer Visitors to the Brittany Shore, by Department, July and August 1979.

	Number of Visitors (x 10^6)	Percent of Total
Finistere	0.66	38
Cotes-du-Nord	0.39	22
Morbihan	0.53	31
Ille-et-Vilaine	0.16	9
TOTAL	1.74	100

Source: Cormier, H. and M. Tessier, 1980: Les Vacanciers sur le Littoral Breton en Juillet-Aout 1979. Institut National de la Statistique et des Etudes Economiques, Direction Regionale de Rennes, Rennes, France (September).

Table 5–2.—Average Characteristics of Visitors to Brittany Shore, by Type of Accommodation, July and August 1979.

	Type of Accommodation			
	Second Residences	Rented Rooms	Free Rooms[a]	Tent or Caravan
Average household expenditure per visit[b] (FR x 10^3)	3.6	5.4	2.3	3.0
Average persons per household (no.)	3.1	3.4	2.9	3.4
Average length of visit (days)	31	24	24	23
Average expenditure per person per day (FR)	37	67	34	38

a "Free rooms" means staying with friends or relatives, paying no rent.

b Included are expenditures on transportation, retail food, lodging, restaurants, travel during vacations, and miscellaneous other purchases.

Source: Cormier, H. and M. Tessier, 1980: Les Vacanciers sur le Littoral Breton en Juillet-Aout 1979. Institut National de la Statistique et des Etudes Economiques, Direction Regionale de Rennes, Rennes, France (September).

ment in tourism-related industries is heavily concentrated along the coast, particularly in Finistere. Table 5–4 shows, for each of the specified tourism-related industries, the percentage of total employment—in that industry in the department—located in the coastal zone. For example, 82 percent of employees in the bakery industry in Finistere in 1975 were located in the coastal zone.

Table 5–5 shows that only 62 percent of the active workers in the indicated tourism-related industries in Brittany were salaried in 1975. The others were self-employed in owner-operated establishments or depended entirely on tips and gratuities for income.

ESTIMATING ECONOMIC LOSSES TO THE TOURIST INDUSTRY

In the introduction to this chapter, it was shown that the decrease in total revenue to the tourist industry represents an upper limit to the possible losses incurred by the industry. This section begins with a description of an attempt to estimate the decrease in total revenue to the industry and follows with a discussion of modifications of that estimate to obtain a figure closer to the actual economic loss. Then two other methods for estimating the losses to the tourist industry, both based on loss in labor earnings in the industry, are discussed and the results of their applications presented.

Estimating the Loss in Total Revenue to the Tourist Industry

Cormier and Tessier (1980) estimated that 1.74 million persons visited the Brittany coast during the months of July and August 1979, and about 2.32 million came during the entire year. Assuming that the same number of visitors would have come in all of 1978 if there had been no oil spill provided the basis in Chapter 4 for estimating the number of tourists who did not come to the Brittany coast in 1978 because of the spill. The estimate was developed by using estimated decreases in occupancy rates of 15 percent for camping, 10 percent for hotels, and 7.5 percent for other types of accommodations. These rates were then applied to the assumed normal number of visitors to yield an estimated decrease of about 245 thousand in the number of visitors in 1978. This decrease in the number of visitors can be translated into the decrease in the number of households which did not come in 1978, using the average size of household by type of accommodation from Table 5–2. Finally, applying the average expenditures per household by type of accommodation to the respective decreases in number of households yields the estimated gross reduction in tourist expenditures. These data are shown in Table 5–6. The estimated reduction in expenditures by visitors who did not come in 1978 is about 240 million 1978 francs.

The estimated reduction in tourist expenditures of about 240 million francs is a flawed measure of economic

Table 5-3.—Total Employment in Tourism-Related Industries, by Department and Total for Brittany, 1975.

Industry and Industry Code (NAP 1973)[a]	Number of Employees (x 10^3) Finistere	Cotes-du-Nord	Ille-et-Vilaine	Morbihan	Total for Brittany
Bakery (38)	2.8	1.7	2.1	2.1	8.7
Wholesale food trade (57)	8.3	4.9	5.3	4.6	23.1
Retail food trade (62)	7.8	4.3	6.2	5.2	23.5
Retail non-food trade (63)	12.5	7.0	11.4	7.7	38.6
Hotels, cafes, and restaurants (67)	9.1	5.5	7.3	6.1	28.0
Transportation[b] (69)	3.3	1.6	3.4	2.7	11.0
Recreation (86)	0.7	0.5	1.7	0.5	3.4
Miscellaneous services (87)	3.2	1.9	3.2	2.1	10.4
Totals	47.7	27.4	40.6	31.0	146.7

[a] NAP 1973 is the industrial classification nomenclature, Nomenclature d'Activites et de Produits, adopted officially in 1975.

[b] All transportation sectors except railways are included.

Source: Institut National de la Statistique et des Etudes Economiques, 1977, Recensement General de la Population de 1975, Region Bretagne, Direction Regionale de Rennes, Rennes, France.

losses for at least two reasons. First, no attempt was made to adjust the estimates for extraordinary revenues received by the tourist industry immediately after the spill and throughout the period of cleanup. Second, no attempt was made to include a change in expenditures made by local residents for their presumed decreased use of services of the tourist industry. These two factors would operate in opposite directions. Ignoring the first causes the estimated reduction in expenditures to be biased upward; ignoring the second causes the estimated reduction in expenditures to be biased downward.

Changes in expenditures, even if measured properly, would be a poor measure of the actual economic loss to the tourist industry of Brittany. Several factors act in concert to cause this to be an upward biased estimator. First, there is no adjustment for alternative uses of the material inputs to the tourist industry, e.g., gasoline, flour, and linens. Second, no allowance is made for the possibility that labor inputs no longer needed by the industry could find alternative employment. Third, even if labor inputs remained unemployed, the increased leisure time might have some value.

A more accurate measure of the actual losses to the tourist industry would take into account the above mentioned factors, namely: offsetting gains during the period of cleanup; additional losses because of reduced patronage by local residents; alternative uses of productive resources released by the tourist industry, both material and labor; and the value of leisure to the unemployed. Several adjustments can be made to the estimated reduction in tourist expenditures to produce a better estimate of economic losses.

First, consider possible offsetting gains during the cleanup period. Activity during cleanup amounted to about 5 thousand men over approximately 100 days. This compares with an estimated reduction of 245 thousand visitors each of whom normally spends about 20–30 days in the shore area. Thus the cleanup activity represented, at most, about 10 percent of the number of visitor-days of tourism lost. Cleanup personnel probably spent less in the region than did the average member of a tourist household, although the latter includes children and the cleanup personnel did not. Assume that a cleanup worker spent one-half the average expenditures per day of

Table 5–4.—Percentage of Employment in Tourism-Related Industries Located in the Coastal Zone of Brittany[a], by Industry and Department, 1975.

Industry and Industry Code (NAP 1973)[b]	Department			
	Finistere	Cotes-du-Nord	Ille-et-Vilaine	Morbihan
	All values in percent			
Bakery (38)	82	55	20	52
Wholesale food trade (57)	77	47	14	62
Retail food trade (62)	88	64	18	62
Retail non-food trade (63)	88	70	18	69
Hotels, cafes, and restaurants (67)	84	61	21	59
Transportation[c] (69)	82	64	13	62
Recreation (86)	84	65	12	67
Miscellaneous services (87)	90	67	15	68

[a] The coastal zone is defined by the communes within each department which border the ocean or the English Channel.

[b] NAP 1973 is the industrial classification nomenclature, Nomenclature d'Activites et de Produits, adopted officially in 1975.

[c] All transportation sectors except railways are included.

Source: Institut National de la Statistique et des Etudes Economiques, 1977, Recensement General de la Population de 1975, Region Bretagne, Direction Regionale de Rennes, Rennes, France.

visitors in 1979, i.e., one-half of the average of about 40 francs shown in Table 5–2, or about 20 francs. Thus, the additional expenditures during the cleanup period may have amounted to about 10 million francs, or about 4 percent of the loss in tourist expenditures. Subtracting 10 million francs from the original estimate of 240 million yields an amended estimate of about 230 million 1978 francs.

Second, certain resources could be redeployed, lessening the economic loss. The values of resources in alternative uses—in economic terms the "opportunity costs" of the resources—are not directly observable. Hence, indirect methods of estimation have to be used, such as the results of previous studies. For example, with respect to the opportunity cost of labor, Haveman and Krutilla (1968) studied the social costs of a number of United States water resources projects. They found that the opportunity cost of labor used in these projects ranged from 65 to 94 percent of the market cost, depending on the region and project. Unemployment figures for the project regions in the Haveman and Krutilla study typically ranged between 8 and 9 percent, 1 or 2 percent above comparable figures for the Brittany region in the summer of 1978. It might then be concluded that the opportunity cost of labor in Brittany during the summer of 1978 was somewhat higher than Haveman and Krutilla found in the United States. However, such a conclusion would ignore several features of the tourist industry in Brittany, e.g., a preponderance of small, family-owned operations, and few alternative employment opportunities in the short run. Consequently, an opportunity cost of labor of 50 percent of market wages was assumed. For similar reasons, capital invested in the Brittany tourist industry is not mobile in the short run. Therefore, it too should be assigned a relatively low opportunity cost; 50 percent was assumed. Applying these assumptions for labor and capital in the tourist industry to the 230 million francs reduces the estimated economic loss to 115 million 1978 francs.

Third, local residents had the choice of going elsewhere than the polluted beaches. In Chapter 4 it was estimated

Table 5–5.—Percentage Salaried Workers Are of Active Workers in Tourism-Related Industries in Brittany, by Industry and Department, 1975.

(Salaried Workers/Active Workers) x 100%					
	Department				
Industry and Industry Code (NAP 1973)[a]	Finistere	Cotes-du-Nord	Ille-et-Vilaine	Morbihan	Brittany
Bakery (38)	49	38	47	38	44
Wholesale food trade (57)	89	87	84	87	87
Retail food trade (62)	52	48	51	58	53
Retail non-food trade (67)	65	60	65	61	63
Hotels, cafes, and restaurants (67)	43	38	55	46	46
Transportation[b] (69)	82	77	87	85	84
Recreation (86)	45	35	78	51	61
Miscellaneous services (87)	66	55	64	64	63
All tourism-related industries	63	57	65	62	62

[a] NAP 1973 is the industrial classification nomenclature, Nomenclature d'Activites et de Produits, adopted officially in 1975.

[b] All transportation sectors except railways are included.

Source: Institut National de la Statistique et des Etudes Economiques, 1977, Recensement General de la Population de 1975, Region Bretagne, Direction Regionale de Rennes, Rennes, France.

that some 14 thousand local residents who would have used tourist facilities on the Brittany coast chose to go elsewhere because of the oil spill. Such transfer of recreation activities to other areas meant some losses to the tourist industry in Brittany. However, lack of data on these transfers precluded making any estimate of the resulting losses. Ignoring these losses means that the estimate of 115 million francs is an underestimate by some unknown amount.

The figure of 115 million francs thus becomes one estimate of the economic loss to the tourist industry as a result of the spill. The following sections describe two other methods that were used to estimate the economic loss to tthe tourist industry. Both of these methods rely on econometric techniques to estimate the impacts of the oil spill on real wage payments in the industry. Based on a loss in real wage payments, the loss in earnings on capital invested in the tourist industry can be estimated.

Estimating Losses in Earnings of Labor and Capital

Losses in Labor Earnings

Because of the extensive reliance on losses in labor earnings to estimate losses to the tourist industry, it is important to examine the theory behind such losses. A loss in labor earnings occurs to the extent labor receives lower wages or is made unemployed as a result of an event such as the Amoco Cadiz oil spill. Figure 5–2 portrays the hypothetical labor market for a tourism-related industry in Brittany in 1978. The short-run labor supply curve facing the industry, S_L, slopes upward to the right. The supply curve indicates the minimum amount that must be paid to bring forth the additional unit of labor; a wage above this amount results in an economic rent to all previous units of labor.

A decrease in demand for the output of a tourism-related industry leads to a reduced derived demand for

Table 5–6.—Estimated Reduction in Visitation and Estimated Reduction in Expenditures by Tourists in Brittany, by Type of Accommodation, 1978.

	Type of Accommodation			Total
	Hotel[a]	Camping[b]	Others[c]	
Reduction in Visitation				
Decrease in visitation[d] (%)	10	15	7.5[e]	--
Decrease in number of visitors[d] (x 10^3)	18.7	134.7	92.0	245.4
Decrease in number of households[f] (x 10^3)	5.5	39.6	30.7	75.8
Reduction in expenditures[g] (1978 FR x 10^6)	30	119	92	241

[a] Assumed to correspond to "rented rooms" in Table 5-2.

[b] Assumed to correspond to "tent or caravan " in Table 5-2.

[c] Assumed to correspond to the average of "second residences" and "free rooms" in Table 5-2.

[d] See Chapter 4, Table 4-2.

[e] Represents the mid-point of the range estimated for this activity, as shown in Chapter 4, Table 4-2.

[f] Based on average number per household from Table 5-2.

[g] Based on average expenditure per household from Table 5-2, i.e., 5.4 thousand, 3.0 thousand, and 3.0 thousand, for hotels, camping, and others, respectively. Average expenditures by type of accommodation assumed to be the same throughout the year.

labor (and for other inputs). In Figure 5–2, D_LD_L represents the demand for labor by the tourist industry in the absence of the oil spill; $D'_LD'_L$ is the actual demand for labor by the tourist industry following the spill.

The short-run supply curve of labor is taken to be inelastic over the range of the decrease in the industry's demand for labor. There are several reasons to believe this is so. One, the seasonal labor force in tourism-related businesses in Brittany is composed largely of local residents. Two, Brittany is a relatively less developed region of France, so that there are few employment alternatives in the short run. Three, many of the tourism-related businesses in the polluted zone are small, family-owned operations. For example, in Finistere and Cotes-du-Nord less than one-half of the work force in the Hotels, Cafes, and Restaurants industry is salaried. Therefore, it is reasonable to expect that the owners and their families will accept lower (implicit) labor earnings, as well as lower earnings on their investments, rather than shut down their activities.

The short-run response in the labor market to a decrease in demand for tourist industry outputs can take two forms. One, labor may be made unemployed. Two, labor may be retained in the short run but produce a lower output. Each of these possibilities is discussed in turn.

With respect to the first, the effect of a decrease in demand for labor is illustrated in Figure 5–2; that is, the amount of labor demanded shifts from L to L'' as a result of the oil spill. At the same time, the wage rate offered by individual businesses in the industry is not flexible in the short run, and the amount of labor demanded with the oil spill, L'', is less than the demand without the spill, L. Therefore, $L - L''$ units of labor are made unemployed. The drop in measured wage payments may be as large as **ca**LL'', but the *actual* loss in welfare suffered by workers is **cabd**, because the area below the supply curve of labor reflects the opportunity cost of paid or unpaid alternative uses of the time of the workers.

About 60 employees in tourism-related businesses were reported fully or partially unemployed as of June 1978, as a result of the Amoco Cadiz oil spill (CODDAF, 1979).[4] However, there is no evidence that the spill led directly to widespread worker layoffs immediately following the spill. On the other hand, the vacation season began late in 1978 and an estimated 185 thousand visitors

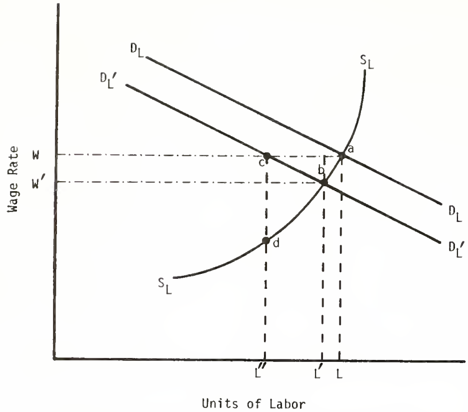

Figure 5-2.—Short-Run Demand and Supply for Labor, Hypothetical Tourism-Related Industry in Brittany, 1978.

did not come to the beaches of Brittany during the 1978 summer season because of the oil spill. Thus, rather than laying off workers, employers may have delayed hiring or hired less labor than they would have in the absence of the spill.

The second short-run response that took place in the labor market in Brittany during the summer of 1978 was that workers produced a lower output per period and many received a lower effective wage. This argument is especially relevant for waiters, waitresses, and other service workers who rely on gratuities from summer visitors for a portion of their income. With fewer visitors, workers in this category accommodate fewer customers and receive fewer gratuities per period, although the wage paid by the individual business does not change. This argument also applies to the owners of the many small, family-operated establishments in Brittany, who can be viewed as accepting lower, implicit labor earnings rather than shutting down their businesses.

In summary, in order to estimate lost labor earnings in the Brittany tourist industry, it is necessary to adjust the measured change in wage payments to take into account two factors. First, an estimate must be made of the loss in implicit wage payments suffered by unsalaried workers. This adjustment is made using a ratio of total-to-salaried employees for each of the tourist industries studied. Second, the loss in gratuities must be taken into consideration. This adjustment is accomplished by assuming that gratuities are equal to 30 percent of actual and implicit wage payments received by service personnel, the percent suggested in Centre d'Etude des Revenus et des Couts (1973, p. 37).

Lost Earnings on Capital

A loss in earnings on capital occurs to the extent that owners of capital invested in the tourist industry received lower earnings or incurred losses. In the short run, capital that has been invested in fixed assets in the tourist industry is essentially immobile. It is not available to be used in other activities. Thus, owners of this capital were not free to shift their investments in anticipation of the decrease in visitors in 1978. However, capital in short-term investments, such as inventories and cash for business transactions, is more mobile and could presumably earn returns elsewhere.

Conceptually, estimates of the lost returns to capital could be made through a detailed examination of the financial accounts of Brittany tourist establishments, taking into consideration all of the factors which would have influenced the demand for goods and services by tourists had the spill not occurred. Examples of relevant factors are weather, income, and prices. This approach could not be used because the appropriate information at the establishment level is not reported by the French government. The only feasible alternative was to use historical relationships between profits and wages as reported by the French government, adjusting where possible for differences in the average size of establishments and the composition of the industry among subclassifications for which profit-to-wage ratios were reported. This approach for estimating losses leaves much to be desired, because earnings on capital are a residual after other inputs have been paid. It is reasonable to expect that earnings on capital will be much more volatile than are payments to labor. Therefore, the use of historical data on normal profit-to-wage ratios, coupled with an estimate of the decrease in wage payments in Brittany during 1978, could understate significantly the loss in earnings on capital. Despite this drawback, the approach was used.[5]

Empirical Estimates of Gross Losses in Wage Payments

Two econometric models were developed to analyze losses to the tourist industry in Brittany in 1978 as a result of the oil spill. Because it was not possible to obtain a time series on tourist industry sales, value added, or other direct measure of output, real wages paid in tourist industries were used as a measure of the level of tourist activity. The wage payments data used were provided by the Institut National de la Statistique et des Etudes Economiques, Direction Regionale de Rennes. Annual data from 1962 through 1976 were based on Declaration Annuelle de Salaires collected by the French tax authority and adjusted to the general population census data of 1962, 1968, and 1975. Quarterly wage payment data from the first quarter of 1977 through the last quarter of 1979 were computed from quarterly growth indices based on data from the Union de Recouvrement de la Securite Sociale et des Allocations Familiales, the social security agency.[6] Both econometric models developed allow for offsetting effects of increased visitation during the period of cleanup and changes in recreation activities of local residents.

The first model is a time-trend model using annual data on real wage payments for the period 1968 through 1976 and quarterly data on real wage payments for the first quarter of 1977 through the fourth quarter of 1979. Because this model uses both annual and quarterly data, it is referred to as the "pooled time-trend model." This model "explains" the behavior of real wage payments in tourist industries over the non-spill period as a simple function of time. The effect of the oil spill on real wage payments is estimated by the use of dummy variables for the second and third quarters of 1978. If the oil spill had an effect on tourism, the signs of the coefficients of the two dummy variables would be expected to be negative and to be statistically significant. A more detailed description of the pooled time-trend model is presented in the Appendix to this chapter.

A time-trend model such as the one described in the preceding paragraph has the advantage of simplicity and relatively small data requirements. In addition, the pooled time-trend model permits use of the available quarterly data. However, a time-trend model is naive and does not provide any information about factors, other than those which can be subsumed under time, which may have caused the observed pattern of real wage payments in tourist industries. That is, the effects of weather, income, and other factors which could have caused real wage payments in tourist industries in 1978 to be below the trend over time are ignored. Thus, deviations below the trend in 1978 may be incorrectly attributed to the oil spill.

In order to overcome the limitations of the pooled time-trend model, an "economic model" was formulated to "explain" annual real wage payments for the period 1962 through 1979 as a function of resident population in the relevant Brittany department, resident per capita real income in France, deviation in mean rain and temperature for the relevant Brittany department, and a time trend. A dummy variable is used for 1978 to capture the effect of the oil spill on real wage payments in that year. Again, the sign on the coefficient for the dummy variable would be expected to be negative and to be statistically significant, if the oil spill had reduced tourism in Brittany in 1978. A more detailed description of the economic model is in the Appendix to this chapter.

The two econometric models were applied to data on real wage payments in four tourism-related industries in Finistere and Cotes-du-Nord, the two Brittany departments physically affected by oil from the Amoco Cadiz. They were also applied to data on real wage payments for the same industries in Morbihan and Ille-et-Vilaine. The coasts of these departments were not affected by oil, but tourism there nonetheless may have been influenced by the oil spill. There are two competing hypotheses. One is that most visitors avoided Brittany altogether in 1978 because of the oil spill and its associated unfavorable publicity. The other is that summer visitors to the region stayed away from the spill zone and instead were diverted to other parts of the region. The analysis of real wage payments in tourism-related industries for Morbihan and Ille-et-Vilaine theoretically should shed some light on which of these two competing hypotheses appears to be more accurate.

For each of Brittany's four departments, four tourism-related industries were analyzed using both econometric models. The sectors of the industries analyzed are shown in Table 5–7. These economic sectors correspond to categories of consumer expenditures reported in surveys of summer visitors to the Brittany shore (Cormier and Tessier, 1980), and represent a large portion of the tourism-related industries in Brittany.

Results of Econometric Analyses of Changes in Wage Payments

The results of the econometric analyses of wage payments using the two models are presented in Table 5-8. The estimates shown are gross losses in wage payments; adjustments for opportunity costs and lost gratuities and implicit wage earnings are made in a subsequent section.

In general, the results depict a consistent pattern of losses in gross wage payments across the four industries and across the four departments of Brittany. Only in the Consumer Services industry in Ille-et-Vilaine and Morbihan does the time-trend model show an increase in wage payments following the oil spill. The economic model shows increases in the Hotels, Cafes, and Restaurants industry in Finistere and in the Consumer Services industry in Morbihan. In every department results show that the Retail Non-Food Trade industry was affected the most. While it may seem surprising that the Hotels, Cafes, and Restaurants industry was affected so much less, it must be remembered that—based on the 1979 study cited previously—a little less than 10 percent of the summer visitors to Brittany stayed in hotels, whereas about 85 percent stayed in second homes, rooms in homes, or in tents and caravans. Moreover hotels, cafes, and restaurants received some unexpected patronage during the cleanup period, particularly in Finistere.

Somewhat contrary to expectations, both models show losses for all four industries combined, in the two departments unaffected by the oil spill—Ille-et-Vilaine and Morbihan—to have been relatively large compared to the losses in Finistere and Cotes-du-Nord. For the pooled time-trend model, the total loss in wage payments in Ille-et-Vilaine and Morbihan was nearly as large as the loss in Cotes-du-Nord and about two-thirds the loss in Finistere. For the economic model, the loss in Ille-et-Vilaine was about 80 percent of the loss in Cotes-du-Nord and about 50 percent of the loss in Finistere; the loss in Morbihan was about 150 percent of that in Cotes-du-Nord and about 90 percent of that in Finistere. Prior expectations would have the losses in Finistere and Cotes-du-Nord much higher than the losses in the departments physically unaffected by oil from the spill. However, it should be emphasized that the standard

Table 5–7.—Tourism Sectors Used in Econometric Analyses.

Industry	Industry Code NAP 1973)[a]	Sector Designation	Activities Included in Sector
Retail food trade	NAP61	Large retail food trade	Supermarkets and supermarket chains
	NAP62	Small retail food trade	Small independent stores, cooperatives, specialty food stores, fruit and vegetable, milk, meat, wine, pastry
Retail non-food trade	NAP63	Non-specialized non-food trade	Large and small, non-specialized and semi-specialized department stores
	NAP64	Specialized non-food trade	Clothing, shoes, leather goods, fabrics, furniture, hardware, household appliances, furnishings, pharmacy, beauty products, motorcycle repair and parts, coal and other fuel, books, stationery, office furniture, optical supplies and cameras, watches and jewelry, flowers, pets, sports and camping equipment, tabacco, miscellaneous
Hotels, cafes, and restaurants	NAP67	Hotels, cafes, and restaurants	With and without lodging, bars, in trains, youth camps, vacation centers
Consumer services	NAP84	Health services	Preventive medicine, general medical hospitals, specialists, clinics, dispensaries, medical laboratories, blood banks, private medical practice, dentists, ambulances, veterinarians
	NAP85	Social services	Kindergarten, handicapped care, elderly care
	NAP86	Recreation and sports	Radio and television production, films, movies, theatres, circuses, recreational instruction, legal gambling, sports centers, sports instruction
	NAP87	Miscellaneous	Laundry, hairdresser, massage, manicure, saunas, baths, funeral services, photographers, cleaners, garbage, water and sewage services

[a] NAP 1973 is the industrial classification nomenclature, Nomenclature d'Activites et de Produits, adopted officially in 1975.

Source: Insitut National de la Statistique et des Etudes Economiques, 1977, Recensement General de la Population de 1975, Region Bretagne, Direction Regionale de Rennes, Rennes, France.

errors surrounding the estimates in most cases include zero, so that the actual pattern of relative losses by industry and department could be quite different from what is reported in Table 5–8 and still be consistent with the estimates of either model.

Estimates of Lost Profits and Lost Labor Earnings

The estimates of lost profits were based on profit-to-wage ratios for each tourist industry.[7] These ratios were obtained for each tourist industry by size of firm, at the national level. The national ratios for each industry were weighted by the size distribution of firms in the industry in the region, in recognition of the differences in the size structure of industries between the region and the nation.[8] The estimated profit-to-wage ratios for the four industries varied by department, but averaged 1.2, 0.95, 0.56, and 0.63 for the Retail Food Trade, Retail Non-Food Trade, Hotels, Cafes and Restaurants, and Consumer Services industries respectively.[9] These ratios were then applied to the estimated losses in wage payments obtained from the two models to derive estimates of lost profits.

Table 5–8.—Econometric Estimates of Lost Wage Payments in 1978 in Brittany Tourist Industries by Department[a].

Industry	Finistere	Cotes-du-Nord	Ille-et-Vilaine	Morbihan	Brittany
	Pooled Time-Trend Model[b]				
Retail food trade	2.9	5.3	4.2	3.2	15.6
Retail non-food trade	17.6	9.5	13.2	9.6	49.9
Hotels, cafes, and restaurants	2.6	4.0	3.9	6.2	16.7
Consumer services	4.0	2.4	-3.1	-0.9	2.4
TOTAL	27.1	21.2	18.2	18.1	84.6
	Economic Model				
Retail food trade	6.6	4.3	6.0	19.4	36.3
Retail non-food trade	39.4	18.0	16.6	31.2	105.2
Hotels, cafes, and restaurants	-0.2	3.8	3.9	4.7	12.2
Consumer services	9.3	7.2	1.1	-5.7	11.9
TOTAL	55.1	33.3	27.6	49.6	165.6

[a] All values in 1978 FR x 10^6
[b] Losses for the pooled model are the negative of the sum of the coefficients of two dummy variables for the summer quarters of 1978.

The additional loss of earnings by self-employed workers was computed using national ratios for tourist industries separated into implicit wage and implicit profit components using the relevant profit-to-wage ratios. Further, losses in gratuities to employees of hotels, cafes, and restaurants were computed as 30 percent of wage payments as suggested in Centre d'Etude des Revenus et des Couts (1973, p.37). Finally, the estimate of lost labor earnings was adjusted to reflect the opportunity cost of labor. As discussed earlier, it was assumed that the opportunity cost of the labor not used in tourist industries was 50 percent of the change in market wages.

The estimated losses derived from the two models are shown in Table 5–9. Lost profits, gratuities, and self-employed earnings were computed by industry and department, based on the procedures described above. Losses implied by the pooled time-trend model are about 125 million 1978 francs; for the economic model the estimated losses are about 250 million 1978 francs.[10]

LOST REGIONAL INCOME FROM FERRY SERVICES

In addition to the components of the tourist industry analyzed above, significant losses may have been incurred in other activities providing services to tourists, such as transportation, e.g., railways, airplanes, and ferries. Sufficient data were not available to be able to estimate the losses to these activities because of the decrease in numbers of tourists to Brittany in 1978. However, one such activity for which some data were available comprised ferry operations, both coastal and international. The former involves the provision of harbor tours, transportation to the scenic islands off the Brittany coast, and travel along the coast. The latter involves transportation between Brittany and particularly England and Ireland.

In recent years an average of about 1.3 million round-trip passengers traveled on Brittany's coastal ferries. In addition, an international ferry service operates between the Brittany ports of Roscoff and St. Malo and ports in England and Ireland. In recent years an average of almost 85 thousand round-trip passengers have traveled between Plymouth, England and Roscoff. About 54 percent of the travel on the international ferries has been during June through August.

The residents of Brittany experienced an economic loss to the extent that profits and labor income in the ferry industry of the region were reduced by the oil spill. In order to estimate the regional economic loss, the assumption was made that the marginal cost of changes in the number of passengers handled was zero. This is a reasonable assumption because no trips were cancelled in 1978, and the crew sizes remained the same. The measure of economic loss is then identical to the change in

Table 5-9.—Estimated Losses in Labor Earnings and Profits in Tourist Industries in Brittany in 1978, from Econometric Analyses.

	Pooled Time-Trend Model	Economic Model
	1978 FR x 10^6	
Wages[a]	42.3	82.8
Gratuities[b]	2.6	1.9
Self-employed earnings	4.1	7.2
Profits[c]	74.9	157.3
TOTAL	123.9	249.2

[a] Opportunity cost of labor assumed to be 50 percent of wage change.

[b] For service personnel in the Hotels, Cafes, and Restaurants industry, gratuities were estimated to be 30 percent of lost wages plus 30 percent of lost implicit wages for self-employed workers, reduced by the assumed opportunity cost of labor of 50 percent.

[c] Includes implicit wages for those firms with few salaried employees.

revenues. Two components of ferry operations were considered, coastal ferries and the Brittany to England ferry services.

Two approaches were used to estimate changes in use of the coastal ferries. One method involved a simple comparison of 1978 use with the average use for the three preceding years. The second method compared the average annual growth rate in demand for the period 1975 through 1977 with the observed changed in demand from 1977 to 1978.

The results from the first method showed an increase in the number of coastal ferry passengers in 1978. However, the second method showed that the number of coastal ferry passengers in 1978 was reduced by 26 thousand or by 38 thousand passengers, for Finistere and Cotes-du-Nord combined. Results from the second method were used for the subsequent analysis. For the region as a whole, the corresponding decreases in demand were estimated to be 19 thousand and 28 thousand passengers. Using an average of 20 francs for each 1978 coastal, round-trip fare, the estimated loss in income is 520 thousand or 760 thousand francs for Finistere and Cotes-du-Nord, the two departments physically affected by oil from the Amoco Cadiz. The estimated loss is 380 thousand or 560 thousand 1978 francs for the region as a whole.

A review of the international ferry statistics of the number of round-trip passengers between Plymouth, England, and Roscoff indicated that the very rapid growth in the number of passengers in the 1972–1975 period was succeeded by a leveling off of growth in the years subsequent to 1975. Accordingly, it does not seem appropriate to consider the years prior to 1975 when making judgements about the number of passengers that would have been expected on the international run in 1978 in the absence of the spill.

If the average demand for the years 1975 through 1977 were used as the best prediction of the number of passengers on the international ferry run in 1978, the conclusion would be that there was an increase in number of passengers in 1978. That is, the number of passengers was larger in 1978 than the average for the preceding three years. However, comparing the 1977 to 1978 increase in use with the average annual increase in use over the 1975–77 period suggests that there was a decrease of 3.6 thousand or 4.9 thousand round-trip passengers on the ferry service between Roscoff and Plymouth. Using an average 1978 round-trip fare of 200 francs per passenger, the estimated loss in regional income is 720 thousand or 980 throusand francs associated with the estimated decreases in the number of international ferry passengers. Thus, the total loss for the regional ferry services is estimated to be 1.1 million to 1.5 million 1978 francs.

DISTRIBUTION OF COSTS TO BRITTANY, FRANCE, AND THE REST OF THE WORLD

Estimates of the losses of profits and labor earnings in the tourist industry as a result of the Amoco Cadiz oil spill has been made by three analytical methods. To these costs have been added lost regional income from

Table 5–10.—Estimated Economic Losses to the Tourist Industry in Brittany in 1978.

Category of Loss and Method of Estimation	Economic Loss, (1978 FR x 10^6)
Lost profits and labor earnings	
Estimated by adjusting loss in total revenues	115
Estimated by pooled time-trend model	124
Estimated by economic model	249
Lost income from ferry services	1
TOTAL ECONOMIC LOSSES TO BRITTANY TOURIST INDUSTRY	116 - 250 (28 - 60)[a]

[a] U.S. dollars x 10^6 at 4.18 francs per dollar.

ferry services to yield the estimated overall economic losses to the tourist industry. The results are summarized in Table 5–10.

By far the most plausible approach is the first, where economic adjustments were made to the estimates of direct reduction in tourist expenditures. The results from the two econometric approaches are less satisfactory because of the great imprecision in the estimates. Losses in the various tourism-related industries of the four departments could typically range from twice those estimated to no loss or even a small gain. The central values that are reported are simply not a good indicator of actual losses. Consequently, in the analysis of distribution of costs which follows, only the results of the first approach are used.

The estimated loss to the tourist industry of about 116 million francs is considered to be distributed as indicated in the following discussion.

1. The loss to Brittany would be the entire 116 million francs, except for some portion of the loss accruing to those assets of the tourist industry in Brittany owned by residents of other regions of France. Because most of the tourism-related businesses in Brittany are relatively small and are of types likely to be locally owned, the amount of non-Brittany ownership is presumed to be small. Therefore, 0 or 5 percent of the losses to the tourist industry, 0 to 6 million 1978 francs, was assumed to have been incurred outside of Brittany; the remainder, 110–116 million 1978 francs, by Brittany.

2. The portion of the loss to the tourist industry borne by France is less than that incurred by Brittany, because some of the foreign tourists who did not visit Brittany went to other destinations in France and because many of the French tourists who did not come to Brittany also probably went to other destinations in France. Finally, the residents of Brittany who did not use the facilities of the tourist industry in the spill zone in 1978 as much as they normally did probably used facilities in nearby areas of France. Starting with the data in chapter 4, assume that half of the 110 thousand foreign tourists who did not go to Brittany in 1978 went to other destinations in France. Assume that 90 percent of the 121 thousand French residents from outside Brittany who did not visit Brittany went to other destinations in France. Finally, assume that essentially all of the 14 thousand French residents from Brittany who chose not to vacation in Brittany went to other destinations in France for their vacations. In such a case, approximately 75 percent of the tourists estimated not to have recreated in the spill zone in 1978 remained in France. Losses to France then would amount to 25 percent of the estimated economic loss of 116 million, or 29 million 1978 francs.

3. The effect on the tourist industry of the rest of the world is actually a gain, because tourists would be expected to have found alternative sites elsewhere in the world. Thus, the losses to the tourist industry of France would be approximately equalled by gains to tourist industries in other countries.

4. The net social cost to the tourist industry of the world is therefore essentially zero. Although tourists suffered some loss in welfare, as discussed in Chapter 4, the tourist industry would not be expected—in the aggregate—to have experienced a decrease in revenues or earnings.

SUMMARY AND CONCLUSIONS

The purpose of this chapter was to estimate the economic loss to the tourist industry in 1978 as a result of the Amoco Cadiz oil spill. Estimates were made of the losses borne by Brittany, by France, by the rest of the world, and by the world as a whole.

Three methods were used to estimate losses in the Brittany tourist industry. The first method estimated the decrease in total receipts of the industry based on

the estimated decreases in number of visitors and their expenditures. The decrease in total receipts, if known accurately, would be an upwardly biased estimate of losses to the industry. Therefore, adjustments were made to the estimate of gross loss in receipts to yield an estimate of net economic loss.

Two other methods, both using econometric analysis, were applied to estimate losses to the tourist industry. Because no direct measures of output of the tourist industry were available, it was necessary to use real wages paid as the indicator of activity for each of the tourism-related industries analyzed.

The first econometric model was a pooled time-trend model, which used both annual data for 1968 through 1976 and quarterly data for 1977 through 1979. The effect of the oil spill was measured by use of dummy variables for the second and third quarters of 1978. This model had the advantage of simplicity and of relatively modest data requirements, and permitted the use of the limited quarterly data available.

The other econometric model can be characterized as an economic model of the tourist industry. This model used annual data for 1962 through 1979 to explain behavior of real wage payments in the tourist industry as a function of real income in France, resident population, rain and temperature in the relevant Brittany departments, and a time trend. The effect of the oil spill was measured by use of a dummy variable for 1978.

Both econometric models were applied to four tourist industries in each of the four Brittany departments: Retail Food Trade; Retail Non-Food Trade; Hotels, Cafes, and Restaurants; and Consumer Services. The estimates of lost wages using the econometric approaches were converted to lost profits using a profit-to-wage ratio for each tourist industry. In addition, the results were adjusted to reflect the loss of gratuities by service personnel and to measure the loss in implicit wages and profits by the many small, family-owned and operated tourism businesses in Brittany.

For all three methods used, an adjustment was necessary to reflect the fact that workers who lost earnings in tourism-related industries had some alternative, productive opportunities open to them. Opportunity costs of 50 percent of lost wages were used to reflect the alternative, productive activities available. Thus a loss of 100 francs in wage payments by a worker in a tourist industry would mean a net loss of 50 francs.

Losses to the tourist industry can be one of the largest *regional* costs of a large oil spill. Many of the problems which confronted the investigators in this study will face analysts attempting to study the effects of future oil spills or other marine pollution incidents. Accordingly, it is useful to summarize some of the key issues and problems encountered in the analysis of the tourist industry.

Expenditures by tourists in a region will be influenced by a variety of factors, including real income, weather, prices, and perhaps other factors such as changes in tastes over time. In attempting to estimate the effect of an oil spill or other marine pollution incident on the tourist industry in a region, the influence of the other factors would ideally be held constant in order to isolate the effects of the pollution incident. This suggests the use of a multi-market, simultaneous system model. Unfortunately, this ideal approach requires a substantial amount of data. In particular, it is necessary to have data for key tourist industries for reasonably small geographic areas and for short intervals of time.

Lacking such data, this study in part based estimates of economic effects on real wage payments, because direct measures of the total output of goods and services for tourists were unavailable. The analysis was done at the broad department level. Because the tourist activities of interest in Brittany departments tend to be located along the coast, the use of departmental data provides a reasonable description of activity for the coastal Brittany tourist industry. Nevertheless, it would have been desirable to have used data for the smaller geographic areas directly affected by the spill, had such data been available.

Also, it would have been desirable to have developed the economic model using quarterly data for variables such as real wages paid in the tourism-related industries, real income, and resident population. However, such data were not available for the pre-1977 period. Consequently, the economic model of tourist activity in Brittany used annual information, except for the rain and temperature variables which reflected seasonal information.

The feasibility of constructing an economic model would be greater for areas of the United States and other countries where time series for the relevant variables may normally be available. For example, wage and employment data, by industry, are gathered at the sub-state level for most areas in the United States on a monthly or quarterly basis. Also, most states levy sales taxes and local governments often levy business and hotel taxes, all of which could be used to help develop an economic model.

In the event that it is not possible to develop an economic model as outlined above, a simple adjustment of lost receipts in the tourist industry has merit as a method of estimating aggregate economic losses to the industry. This method requires relatively few data and appears to yield plausible estimates, as illustrated in this study.

It should be emphasized that individual tourist businesses hoping to receive compensation for oil spill damages would probably need to produce detailed revenue and cost records to receive compensation from government agencies or insurance companies. The results of any of the three methods described above could be used to assist in the processing of individual claims by providing general parameters to set guidelines for evaluating damage claims. For example, one could use the income, weather, and other coefficient estimates of an economic model to develop general rules of thumb to

predict what would have happened to tourism-related industries in the region of concern if there had been no spill. If a particular hotel or restaurant operator had evidence, e.g., advanced, confirmed reservations, that his business would have been greater than that indicated by the rules of thumb, he would have grounds for contesting a settlement.

NOTES

[1] Most of the industry sectors providing services to tourists, e.g., restaurants, cafes, retail food, and bakery, of course also provide similar services to residents of Brittany. Probably the overall demand for such services by the residents also decreased as a result of the oil spill, e.g., because of decreased income. The analytical problem is that of estimating the difference between what the situation would have been in the absence of the spill and what actually occurred as a result of the spill.

[2] Theoretically, in a long-run analysis, if owners of capital anticipate the occurrence of future oil spills and the resulting fluctuations in tourism demand, this information would be reflected in decisions with respect to the types and amounts of capacity to build, and in the market value of tourism facilities at any point in time.

[3] Note that if prices were flexible in the short-run, the market price would drop to P_1 and the economic cost to the region's tourist industry would be P_0P_1**fd.**

[4] CODDAF is the Comite Departmental de Developpement et d'Amenagement du Finistere.

[5] Subsequently, but too late for use in the study, the suggestion was made that the profit-to-wage ratio for a recession period, or the average for several recession periods, be used to approximate the situation in 1978.

[6] The wage and salary data were classified into industrial sectors using the nomenclature in Institut National de la Statistique et des Etudes Economiques (INSEE), Paris (1978). Data prior to 1975, for which a different classification system was used, were transformed using relationships specified in INSEE, Rennes (no date). Annual data for 1962 through 1975 were taken from the annual issues of the INSEE, Rennes publication, *Masses de Salaire Bruts et Effectifs Salaires en Bretagne.* These annual data were adjusted to census estimates for 1962, 1968, and 1975 given in INSEE, Rennes (1977). Data for 1976 were derived from Tregouet (1978). Quarterly data for 1977 through 1979 were taken from an INSEE, Rennes unpublished computer printout on quarterly indices of wages and salaries for Bretagne. Price indices were taken from INSEE, Paris (1979).

A detailed description of the data sources and procedures used to develop the time series of wage payments is contained in a monograph prepared by the authors of this chapter.

[7] Because marginal profit-to-wage ratios will be different than average profit-to-wage ratios, an attempt was made to devise an appropriate model by which to compute marginal ratios from available average data for 1972-75. These data were obtained from the relevant annual issues of the INSEE, Paris publication, *Les Comptes Intermediaires des Entreprises.* Although national output levels for the studied industries varied considerably over the period, no systematic pattern was discovered between average ratios and output over time. Furthermore, an approximation to the adjustment process derived from the theory of the firm was explored but found to be extremely sensitive to assumptions about break-even levels of output and about functional forms. As a result of these problems, weighted average ratios were used in the analysis. These were computed from the ratio of total real profits during 1972–75 to total real wage payments for the same period.

[8] Information on the size distribution of firms in Brittany was obtained from the Association pour l'Emploi dans l'Industry et Commerce, 1976.

[9] The seemingly high ratios reflect the fact that what are recorded as profits for many small Brittany businesses with few salaried employees are in fact implicit wages.

[10] In Chapter 7, the secondary or indirect effects of losses by the Brittany tourist industry in 1978 on income in other industries in Brittany are estimated. The estimated secondary effects in principle capture the effects of reduced tourism on such industries as wholesale food trade and transportation, which provide goods and services used as *inputs* to sales to summer visitors by businesses included in the four industries included in the analyses. Estimated secondary losses are not included here because to do so would be to count the losses twice.

REFERENCES

Centre d'Etude des Revenus et des Couts, 1973: *L'Hotellerie Francaise: Deuxieme Partie; Facteurs de Production et Rentabilite des Entreprises: Rapport de Synthese* (3rd and 4th trimesters, 1972). Paris.

Comite Departmental de Developpement et d'Amenagement du Finistere, 1979: *Note de Synthese sur les Incidences Economiques de la Catastrophe de l'Amoco Cadiz.* Quimper, France (January).

Cormier, H., and M. Tessier, 1980: *Les Vacanciers sur le Littoral Breton en Juillet-Aout 1979.* Institut National de la Statistique et des Etudes Economiques, Direction Regionale de Rennes, Rennes, France (September).

Haveman, R.H., and J.V. Krutilla, 1968: *Unemployment, Idle Capacity, and the Evaluation of Public Expenditures: National and Regional Analyses.* The Johns Hopkins Press, Baltimore, 172 pp.

Institut National de la Statistique et des Etudes Economiques, Ministere de l'Economie et des Finances, 1978: Nomenclatures d'Activites et de Produits 1973. *Journal Officiel de la Republique Francaise,* No. 1402–1. Paris.

__________, 1979: Statistiques et Indicateurs des Regions Francaises, Annexe au Project de Loi de Finances pour 1979, No. 298–299 des Collections de l'Institut National de la Statistique et des Etudes Economiques, Serie R, No. 34–35. Paris.

Institut National de la Statistique et des Etudes Economiques, Direction Regionale de Rennes (no date): *Table de Passage, AE600 x AEN59 Table de Comptage,* Filtre: Actifs Ayant un Emploi. Computer printout for 99 NAP sectors x 99 NAE sectors, by department, from census data. Rennes, France.

__________, 1977: *Recensement General de la Population de 1975, Region Bretagne.* Rennes, France.

Tregouet, B., 1978: 1968–1978: Dix Ans d'Emploi en Bretagne. Service d' Etudes de la Direction Regionale de Rennes, Octant No. 3, Rennes, France (September).

Appendix

ECONOMETRIC ANALYSES OF LOST WAGE PAYMENTS IN THE TOURIST INDUSTRY

Losses to the tourist industry consist of two components, lost labor earnings and reduced earnings on capital. Estimates of lost wages were based on a direct analysis of wage payments in the tourist industry and lost earnings on capital were based on the historical relationship between wages and profits in the industry. Thus, it is essential to model the historical time pattern of actual wage payments in order to compare that pattern with what would have been expected without the oil spill. Two econometric models were developed for this purpose, termed the pooled-time trend model and the economic model. Available data for use consisted of annual data prior to 1977, quarterly data beginning in 1977. These models were applied for four tourism-related industries in each of the four Brittany departments.

THE POOLED TIME-TREND MODEL

The pooled time-trend model was designed to capture growth in real wage payments observed for the quarters of 1977, 1978, and 1979, and also to be consistent with the annual growth in real wage payments from 1968 through 1976. A linear rather than a log-linear trend model was used, so that predicted values would have the proper adding-up properties, i.e., the sum of four quarters of wage payments should equal the annual total. (An exponential growth rate model would not have this property). The linear growth model did not characterize the period 1962 through 1967 well; thus, the observations for this period were omitted from the analysis.

The form of the pooled time-trend model that was specified and applied to the four industries identified previously is

$$\begin{aligned}(W)_s = {} & b_{01}C_{1,s}+b_{02}C_{2,s}+b_{03}C_{3,s}+b_{04}C_{4,s} \\ & + b_{11}T_{1,s}+b_{12}T_{2,s}+b_{13}T_{3,s}+b_{14}T_{4,s} \\ & + d_1 D78_{2,s}+d_2 D78_{3,s}+e_s, \end{aligned} \qquad (5A\text{–}1)$$

where $(W)_s$ = the value of real wage payments in the sth period in millions of francs, obtained by modifying nominal wage payments by the French consumer price index which = 1.0 for the first quarter of 1978;

s = the index for the 21 observations, i.e., for annual data from 1968 through 1976, s ranges from 1 through 9; for quarterly data from quarter 1, 1977, through quarter 4, 1979, s ranges from 10 through 21;

$C_{1,s}/C_{2,s}/C_{3,s}/C_{4,s}$ = intercept dummy variables for the four quarters of the year, such that for annual data all dummy variables equal unity; for quarterly data each dummy variable—$C_{i,s}$—equals unity only when $i=s$ and equals zero otherwise.

$T_{1,s}/T_{2,s}/T_{3,s}/T_{4,s}$ = annual time-trend dummy variables for the four quarters of the year, such that for annual data all dummy variables equal the annual time-trend; for quarterly data each dummy variable—$T_{i,s}$—equals the annual time trend only when $i=s$ and equals zero otherwise:

$D78_{2,s}$ and $D78_{3,s}$ = oil spill dummy variables, such that for the second quarter of 1978, $D78_{2,s}=1$; for the third quarter of 1978, $D78_{3,s}=1$; otherwise all values of the dummy variables = 0;

e_s = the error term for the sth observation, such that for data for the ith quarter of the years 1977 through 1979, e_s is assumed to be normally distributed with a mean of zero and variance of σ^2; for the annual data for 1968 through 1976, e_s is assumed to be normally distributed with a mean of zero and variance of $4\sigma^2$;

$b_{01}, \ldots b_{04}$, $b_{11}, \ldots b_{14}$, d_1, and d_2 are coefficients to be estimated.

The intercept and trend dummy variables have the effect of "turning on" different linear trend models for each of the four quarters of the years 1977, 1978, and 1979. All intercept and trend coefficients are turned "on" for the years 1968 through 1976 so that their sums also correspond to annual intercept and trend terms.

Negative coefficients would be expected for the dummy variables, $D78_{2,s}$ and $D78_{3,s}$, and for the second

and third quarters of 1978, if the oil spill in fact had a negative impact on real wage payments in Brittany's tourism-related industries.

The estimated coefficients and their standard errors for the pooled time-trend model are given in Table 5A–1. The R^2 and Durbin-Watson statistics from the ordinary least squares procedure are also presented, but they are biased because of the stochastic specification. It should also be recognized that, because of the specification of quarterly error terms which add up to the annual error term for each year, the residuals can no longer be assumed to have a common variance, and ordinary least squares will give inefficient estimates. Therefore a weighted least squares procedure was used to estimate the model under the assumption of independence of quarterly errors.

The units of the dependent variable in the regression are millions of francs, so that the coefficients of the dummy variables, which are generally negative, can be interpreted directly as lost real wages. Generally speaking, losses from 1 to 10 million francs were estimated for the Retail Food Trade, Retail Non-Food Trade, and Hotels, Cafes, and Restaurants industries in all departments in both quarters of the 1978 tourist season. Exceptions occurred in Morbihan where the coefficients were positive for the third quarter of 1978 for

Table 5A–1.—Results of Application of Pooled Time-Trend Model of Brittany Tourist Industries, 1968–1979, Inclusive.[a]

Department	C_1	C_2	C_3	C_4	T_1	T_2	T_3	T_4	078_2	078_3	R^2	DW[b]	S^2
Retail Food													
Cotes-du-Nord	11.890 (45.618)[c]	6.895 (45.644)	14.038 (45.644)	11.008 (45.618)	0.946 (4.141)	1.671 (4.141)	1.386 (4.141)	1.638 (4.141)	- 2.753 (8.103)	- 2.562 (8.103)	0.983	0.857	2001.191
Finistere	29.075 (90.457)	36.399 (90.512)	40.179 (90.512)	33.330 (90.457)	1.856 (8.210)	1.522 (8.210)	1.653 (8.210)	2.512 (8.210)	- 2.042 (16.068)	- 0.832 (16.068)	0.986	0.668	7868.903
Ille-et-Vilaine	20.012 (43.002)	20.316 (43.028)	23.598 (43.028)	19.758 (43.002)	0.932 (3.903)	1.042 (3.903)	0.805 (3.903)	1.515 (3.903)	- 1.871 (7.639)	- 2.291 (7.639)	0.992	0.565	1778.166
Morbihan	13.110 (48.916)	13.166 (48.945)	50.514 (48.945)	- 7.284 (48.916)	1.648 (4.440)	2.098 (4.440)	- 1.109 (4.440)	4.108 (4.440)	- 4.779 (8.689)	1.581 (8.689)	0.990	0.816	2300.893
Retail Non-Food													
Cotes-du-Nord	27.674 (77.194)	26.578 (77.241)	27.906 (77.241)	21.451 (77.194)	0.538 (7.006)	0.795 (7.006)	0.778 (7.006)	1.445 (7.006)	- 4.517 (13.712)	- 4.958 (13.712)	0.979	0.572	5730.152
Finistere	49.232 (148.702)	56.134 (148.792)	49.619 (148.792	55.390 (148.702)	1.303 (13.497)	1.132 (13.497)	1.826 (13.497)	1.372 (13.497)	- 8.280 (26.413)	- 9.319 (26.413)	0.981	0.561	21263.939
Ille-et-Vilaine	39.200 (134.795)	49.197 (134.876)	47.396 (134.876)	52.426 (134.795)	2.324 (12.234)	1.832 (12.234)	1.852 (12.234)	1.724 (12.234)	- 7.420 (23.943)	- 6.192 (23.943)	0.981	0.793	17473.848
Morbihan	27.463 (96.326)	28.189 (96.385)	28.077 (96.385)	33.761 (96.326)	1.029 (8.743)	1.283 (8.743)	1.430 (8.743)	0.922 (8.743)	- 5.184 (17.110)	- 4.409 (17.110)	0.977	0.609	8923.439
Hotels, Cafes, and Restaurants													
Cotes-du-Nord	1.059 (31.450)	3.881 (31.469)	11.120 (31.469)	10.183 (31.450)	0.656 (2.854)	0.545 (2.854)	0.134 (2.854)	0.067 (2.854)	- 1.467 (5.586)	1.586 (5.586)	0.973	0.273	951.145
Finistere	- 1.745 (41.296)	6.662 (41.322)	25.676 (41.322)	10.470 (41.296)	1.969 (3.747)	1.535 (3.747)	0.421 (3.747)	1.024 (3.747)	- 0.719 (7.335)	- 1.265 (7.335)	0.991	0.596	1640.052
Ille-et-Vilaine	10.491 (28.407)	7.982 (28.324)	10.555 (28.324)	9.117 28.307)	0.829 (2.569)	1.304 (2.569	1.292 (2.569)	1.101 (2.187)	- 1.491 (5.029)	1.509 (5.029)	0.992	0.667	770.489
Morbihan	22.738 (24.094)	15.839 (24.108)	- 9.950 (24.108)	- 5.743 (24.094)	- 0.662 (2.187)	0.310 (2.187)	3.407 (2.187)	2.218	- 1.606	3.139	0.994	0.817	558.270
Consumer Services													
Cotes-du-Nord	11.136 (31.220)	34.507 (31.238)	12.384 (31.238)	14.979 (31.220)	1.497- (2.833)	0.586 (2.833)	1.646 (2.833)	1.541 (2.833)	- 0.702 (5.515)	- 1.703 5.545)	0.994	0.967	937.335
Finistere	29.301 (64.240)	20.608 (64.279)	40.398 (64.279)	47.413 (64.240)	2.348 (5.831)	3.534 (5.831)	1.918 (5.831)	1.387	- 3.558 (5.831)	- 0.431 (11.410)	0.993 (11.410)	0.816	3968.117
Ille-et-Vilaine	23.187 (74.987)	21.844 (75.032)	24.240 (75.032)	35.732 (74.987)	5.585 (6.806)	5.859 6.806	5.940 (6.806)	5.335 (6.806)	- 0.736 (13.320)	2.393 (13.320)	0.994	1.569	5407.529
Morbihan	11.698 (33.090)	22.139 (33.111)	20.909 (33.111)	28.373 (22.090)	2.518 (3.004)	1.741 (3.004)	2.057 (3.004)	1.432 (3.004)	0.429 (5.877)	0.505 (5.877)	0.996	1.221	1027.785

[a]The dependent variable is real wage payments. The model was estimated using ordinary least squares procedures. The R^2 and DW estimates are not unbiased.

[b]DW = Durbin-Watson statistic.

[c]Standard errors in parentheses.

the Retail Food Trade and Hotels, Cafes, and Restaurants industries. Smaller losses were estimated for Cotes-du-Nord and Finistere, i.e., 0.4 and 3.6 million francs, respectively, and gains were estimated for the other departments. The results for the fourth industry category, Consumer Services, showed a lack of sensitivity to the effects of the oil spill. The lack may well reflect the wide diversity of health, social, recreational, and miscellaneous services represented in this industry category. Many of these services are not seasonal and are not dependent on the tourist population.

With 11 degrees of freedom, few of the 10 coefficients in the 16 equations are significant at any reasonable level. On one hand, this is very discouraging in that confidence intervals around the estimated coefficients are very wide and in most cases include zero. On the other hand, this does not imply that the effects of time and the oil spill on real wage payments are truly zero, only that zero cannot be rejected as a possibility with this sample, assuming that the model as postulated is the true model. At best what can be said is that these coefficients are the most efficient, linear, unbiased estimates possible for the above model.

THE ECONOMIC MODEL

The theoretical economic model for the analysis of the effects of the oil spill on real wage payments in the tourist industry could not be applied because of lack of data. No sales, value added, or relevant tax data were available, and no suitable seasonal or annual counts of tourists were available, for Brittany, its departments, or the coastal zone. Consequently a simpler model was formulated, which kept some of the sense of the theoretical model.

Although the time-trend model of the last section accounted for a considerable proportion of the variation in real wage payments, it did not provide any explanation for deviations in the observed data from the time trend. The effects of changes in factors such as weather, household income, and foreign exchange rates on real wage payments in 1978 were all attributed to time or to the oil spill.

The form of the economic model that was specified and applied to the four industries identified previously is

$$\log (W_t)=b_0+b_1 \log (Y_t)+b_2 \log(POP_t) + b_3(TEMP_t)+b_4(RAIN_t)+b_5T_t+dD78+e_t, \quad (5A\text{–}2)$$

where

W_t = the value of real wage payments in the tth year in thousands of francs, obtained by modifying nominal wage payments by the consumer price index for France for year t, where $1978=1.0$;

Y_t = resident real per capita income in France in year t francs, obtained by modifying nominal per capita income by the consumer price index for France for year t, where $1978=1.0$;

POP_t = population of the department in year t, thousands

$TEMP_t$ = deviation of mean temperature in the third quarter of the tth year from the 30-year average, 1931–1960, for the department, degrees centigrade;

$RAIN_t$ = deviation of mean precipitation in the third quarter of the tth year from the 30-year average, 1931–1960, for the department, millimeters;

T_t = an index of years, 1 to 18;

$D78$ = a dummy variable for 1978;

t = 1962, ...1979;

b_0 = intercept;

$b_1,...b_5, d$ = coefficients to be estimated; and

e_t = the error term for the tth year.

This model can be viewed as the sum of logarithmic reduced-form equations for the wage rate and number of hours worked, from a simultaneous equations model of the market for tourism-related goods and services and the associated labor market. Other explanatory variables, such as hotel capacity and a composite foreign exchange rate, were also tested in this model, but were ultimately deleted because of collinearity with the variable $D78$.

The results for the economic model are presented in Table 5A–2. The R^2 statistics indicate a high degree of statistical explanation of the variability of the logarithm of real wage payments, and the Durbin-Watson statistics indicate no serious autocorrelation of residuals. However, the standard errors of the estimates are often high. The coefficients generally agree with expectations for the effects of the population and the income variables and disagree with expectation of the effects of the rain and temperature variables. Time was found to have a negative influence on real wage payments, when all other factors were held constant.

The size of the standard errors on the dummy variable for the spill are again not small enough to permit uniform rejection of zero effects at any reasonable level of significance. On the other hand, the confidence intervals for this model are somewhat smaller than those of the pooled time-trend model. At least four of the oil spill effects are significant at the 90% level, three of them in the Retail Non-Food Trade industry.

Table 5A-2.—Results of Application of Economic Model of Brittany Tourist Industries, 1962–1979, Inclusive.[a]

Oepartment	Intercept	Population	Temperature	Rain	Y[b]	Time	D78	R^2	DW[c]	s^2
Retail Food										
Cotes-du-Nord	- 111.467	17.855	0.0295	0.008	2.815	- 0.075	- 0.044	0.9909	2.003	0.00372
	(24.111)[d]	(3.845)	(0.0313)	(0.002)	(0.449)	(0.024)	(0.073)			
Finistere	- 50.648	7.422	0.033	0.002	3.533	- 0.100	- 0.031	0.9886	1.514	0.00272
	(39.607)	(6.084)	(0.044	0.003	(0.461)	(0.029)	(0.061)			
Ille-et-Vilaine	- 130.877	20.641	- 0.005	- 0.003	2.343	- 0.224	- 0.048	0.9842	2.156	0.00375
	(57.369)	(9.162)	(0.029)	(0.005)	(0.671)	(0.076)	(0.075)			
Morbihan	- 44.859	7.189	- 0.085	- 0.004	2.715	- 0.051	- 0.133	0.9839	1.7291	0.00516
	(36.405)	(5.772)	(0.053)	(0.006)	(0.524)	(0.034)	(0.097)			
Retail Non-Food										
Cotes-du-Nord	- 20.170	2.162	- 0.008	0.007	5.124	- 0.125	- 0.133	0.9906	1.8223	0.00272
	(20.628)	(3.290)	(0.027)	(0.002)	(0.384)	(0.020)	(0.063)			
Finistere	- 17.679	1.782	- 0.026	0.002	5.094	- 0.131	- 0.152	0.9756	1.3016	0.006036
	(58.923)	(9.051)	(0.065)	(0.004)	(0.685)	(0.043)	(0.091)			
Ille-et-Vilaine	- 136.278	21.135	- 0.008	- 0.004	3.357	- 0.268	- 0.065	0.9817	1.7877	0.004407
	(62.174)	(9.929)	(0.032)	(0.005)	(0.727)	(0.083)	(0.081)			
Morbihan	- 23.781	2.817	- 0.070	0.002	4.976	- 0.125	- 0.188	0.98	1.4673	0.005713
	(38.311)	(6.074)	(0.056)	(0.006)	(0.551)	(0.036)	(0.102)			
Hotels, Cafes, and Restaurants										
Cotes-du-Nord	- 113.963	17.813	0.059	0.003	3.586	- 0.132	- 0.085	0.9316	1.3025	0.016286
	(50.450)	(8.046)	(0.066)	(0.005)	(0.939)	(0.050)	(0.153			
Finistere	- 132.502	20.953	0.061	0.0003	0.604	- 0.062	- 0.0002	0.9777	1.4423	0.006556
	(51.409)	(9.433)	(0.068)	(0.004)	0.715)	(0.045)	(0.095)			
Ille-et-Vilaine	- 169.245	27.468	0.038	- 0.002	0.259	- 0.193	- 0.038	0.9805	1.817	0.0074
	(80.564)	(12.866)	(0.041)	(0.007)	(0.943)	(0.107)	(0.105)			
Morbihan	- 131.628	21.120	0.089	0.112	2.133	0.052	- 0.049	0.9955	1.8017	0.002837
	(29.996)	(4.280)	(0.039)	(0.004)	(0.388	(0.026)	(0.072)			
Consumer Services										
Cotes-du-Nord	- 24.229	4.125	- 0.018	0.005	2.339	- 0.036	- 0.062	0.9784	2.4158	0.004402
	(26.229)	(4.183)	(0.034)	(0.002)	(0.488)	(0.026)	(0.079)			
Finistere	- 15.121	2.462	0.016	0.004	2.632	- 0.040	- 0.040	0.9868	1.6628	0.0029239
	(41.010)	6.299	(0.045)	0.003	0.477	(0.029)	(0.063)			
Ille-et-Vilaine	- 22.000	5.477	0.011	0.003	-1.417	0.091	- 0.008	0.9467	2.4276	0.021405
	(137.019)	(21.882)	(0.069)	(0.011)	(1.603)	(0.183)	(0.179)			
Morbihan	- 23.364	4.572	0.031)	0.011	1.102	0.011	0.033	0.9780	1.7237	0.00503148
	(35.954)	(5.700)	(0.053)	(0.006)	(0.517)	(0.034)	(0.096)			

[a]Dependent variable is the log of real wage payments.

[b]OW = Ourbin-Watson statistic.

[c]Resident per capita income.

[d]Standard errors is parentheses.

Chapter 6

OTHER COSTS

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INTRODUCTION

Although most of the measurable social costs of the Amoco Cadiz oil spill have been presented in the previous chapters, a few categories of losses remain to be discussed. These are the values of the lost cargo and lost ship at the time of the accident; legal costs; expenditures on research relating to the oil spill; damages to agricultural crops; and damages to human health.

These categories of losses represent a diverse collection of public and private damages. Except for damages to human health, estimates can be made of their magnitudes using market prices. However, it is difficult to know for some of these cost categories exactly what fraction of the identified costs was incurred because of the Amoco Cadiz oil spill. For example, with respect to research on the fates and effects of the spilled oil, there is no objective way to determine how much of each of the identified research budgets was directly related to the Amoco Cadiz oil spill. The problem is that the spill was seen by scientists from around the world as an opportunity to conduct research on the effects of spilled oil in the marine environment. The results of the extensive research that has been undertaken will have varied uses in formulation of policies on oil spills and in applications to other environmental quality management problems. Thus, while the Amoco Cadiz oil spill provided a laboratory-like situation for conducting research, it would be erroneous to charge all of the costs of the research identified to that one spill. However, the cost of research relating to the Amoco Cadiz oil spill is not the only cost category evaluated in this report for which a separability problem existed. For example, in estimating cleanup costs (Chapter 2), a decision had to be made with respect to the portions of capital costs of purchased and existing equipment to be allocated to the Amoco Cadiz oil spill and to previous and future uses of the equipment.

Two other types of data problems were encountered. One involved unavailable data, as in the case of legal costs, or insufficient evidence, e.g., concerning damages to human health. The other involved the difficulty in knowing specifically when some costs were actually incurred. For example, research and legal costs have been incurred for more than 3 years since the spill, with no end in sight. Other costs, such as those of the lost cargo and vessel, were incurred at the time of the accident. Those costs whose specific dates of occurrence were unknown were assumed to have been incurred in 1978. Thus, none of the estimates of these costs has been discounted. For costs which actually were incurred subsequent to 1978, this assumption results in some unknown, but believed small, degree of overestimation of costs.

VALUE OF THE LOST CARGO

Each of the approximately 220 thousand tons of crude oil lost from the Amoco Cadiz was reported to have been worth about 454 francs on the world market at the time of the accident (Kiechell, 1979). Virtually all of this oil was lost. A small amount was recovered at the refineries where cleanup wastes were taken, but the actual quantity and the final disposition thereof are not known. Thus, the entire value of the cargo, i.e., about 100 million francs, was treated as a loss. Further, because the oil was a commodity moving in world trade, it was classified as a cost to the world and not to a single country or region.

VALUE OF THE LOST TANKER

There are at least two possible approaches to valuing the loss of the ship. One is to use replacement cost. At the time that the Amoco Cadiz was built, 1973, it would have sold for approximately 210 million francs. In 1978, the replacement cost for a tanker of the same design would have been approximately 293 million francs.[1] This latter figure, while determined in the market place, does not necessarily represent the actual *economic* value of the ship *at the time of the accident*. Various adjustments have to be made to account for wear and tear on the vessel and the overall condition of the tanker market in 1978.

A more direct approach would have been to use the amount of hull insurance carried on the vessel by the owner at the time of the accident, 63 million francs. However, rarely is a vessel insured for 100 percent of its market value, so that the 63 million probably represents some degree of underestimation of the market value of the vessel at the time.

Another figure was provided by the Amoco fleet insurance office, which stated that the company considered the vessel to be worth approximately 100 million francs when it went down (Flink, 1981). This figure represents the depreciated book value of the vessel to the company, some 37 million francs more than the insured value. Because of a change in company policy regarding hull insurance following the accident, Amoco now tries to insure each of its vessels up to its full book value, less any deductibles which Amoco may carry on its policies.

The actual social cost of the lost vessel at the time of the accident probably was between the insured value, 63 million francs, and the depreciated book value, 100 million francs.[2] These two figures are used in subsequent tabulations.

Most of the loss was insured and the balance of it was taken by the company. Thus, only a very small percentage of the lost vessel costs would be likely to be borne by citizens of France or Brittany. Therefore, the loss was classified as a world cost.

LEGAL COSTS

Existing laws in the United States and France do not provide well-defined procedures for assessing liability and costs of spills of oil or hazardous materials. Such determinations are usually made through complex adjudicatory proceedings involving extensive legal costs. Thus, an assessment of the social costs of the Amoco Cadiz spill should include the opportunity costs of the additional labor, capital, and any other resources used for legal purposes as a result of the spill.

The costs of the legal proceedings could, conceptually, be measured by summing the amounts actually paid to attorneys and various experts, the value of the time spent by the litigants, and any additional sums spent on miscellaneous activities associated with the case, *over and above* normal expenditures for legal staffs. Any major firm has a full-time legal staff which is responsible for handling day-to-day legal questions. Such activities represent part of the normal costs of doing business. Only if, given a relatively rare event such as that of the Amoco Cadiz oil spill, the services of additional legal staff and various experts had to be purchased, overtime paid to in-house staff, and expenses of witnesses and various extra travel costs incurred, would such costs be attributable to the event. Such expenditures would represent diversions from other presumably productive activities, and therefore would represent opportunity costs to society.

However, standard practice in the legal profession results in treating legal expenses with strict confidentiality. Repeated attempts to establish at least a minimum figure for legal expenditures by questioning a number of the attorneys involved in the Amoco Cadiz case met with no success. The only figure available was one released by the French government on the value of the contribution of the national government to some towns in Brittany seeking to recover damages from the spill. The amount was approximately 400 thousand francs. No additional figures were available and there was no basis on which to make a more complete estimate. Because the total legal expenses are certain to be several or many times higher than this figure, but will probably never be made public, a lower limit on legal costs was assumed equivalent to the known French expenditure, i.e., 400 thousand francs.

It should be noted that essentially all of the legal costs would probably be borne by citizens of France and the United States. However, depending on where the insurance was written, and where those with financial interests in any of the affected companies lived, some of the costs might be borne outside these two countries.

RESEARCH COSTS

In the aftermath of the Amoco Cadiz oil spill, research scientists from around the world converged on Brittany to take advantage of the opportunity to study the fates and effects of the spilled oil. Some of these scientists were directly concerned with that part of the northeast Atlantic coast of France affected by the oil. Others were interested not only in the impacts on the French coast, but also in obtaining information that might be useful to other areas subjected to oil spills. The entire spill zone became a living, outdoor laboratory.[3] As of 1981, several major biological, physical, and chemical studies were still being conducted in the spill zone and adjacent areas. However, the estimated research expenditures do not include costs incurred beyond the spring of 1980.

The major sources of funding for the research reported here were Standard Oil of Indiana (Amoco), the governments of France and the United States, and the European Economic Community. Several other western nations, e.g., Canada, The Netherlands, and the United Kingdom, contributed unknown sums in support of various research projects. The research expenditures which were identified are shown in Table 6–1.

Most United States research expenditures were made through grants managed by the National Oceanic and Atmospheric Administration and the Environmental Protection Agency and totaled about 10 million francs.[4] It was more difficult to estimate French and other non-United States expenditures. Research on the Amoco Cadiz oil spill was undertaken by at least eleven institutions in France with funding from various sources. Most French funding came from the Ministry of Environment and the National Center for Exploitation of the Oceans (Centre National pour l'Exploitation des Oceans).

French research costs which can be accounted for amounted to about 5 million francs. Some support was also provided by the European Economic Community, and unknown amounts were spent by various other for-

Table 6-1.—Research Costs Associated with the Amoco Cadiz Oil Spill by Source of Funding and Type of Research.[a]

Source of funding and type of research	Amount (1978 FR x 10^6)	
United States[b]		
Natural science research		
Standard Oil of Indiana (Amoco)	8.4	
NOAA and EPA[c]	0.3	
Economic research		
NOAA and EPA	1.5	
Subtotal		10.2
France and All Others (Non-U.S.)[d]		
Natural science research		
French Ministry of Environment and Quality of Life and National Center for Exploitation of the Oceans	4.6	
Economic research		
European Economic Community	0.2	
INRA[e]	0.6	
Subtotal		5.4
TOTAL		15.6

[a] Costs are assumed to have been incurred in 1978. For most of the costs indicated this is probably a reasonable assumption, in that the funds were appropriated in 1978 even though not all may have been expended in 1978.

[b] Source: Budget Office, Office of Research and Development, National Oceanic and Atmospheric Administration, September 1980.

[c] NOAA and EPA are the National Oceanic and Atmospheric Administation and Environmental Protection Agency, respectively.

[d] Source: Based on compilation by Richard Congar (1980).

[e] INRA is the Institut National de la Recherche Agronomique located in Rennes, France. The expenditures indicated are for completing the study by Bonnieux, et al. (1980).

eign institutions. As noted above, a major problem with respect to research expenditures was to find a satisfactory way to assign the appropriate amount of the total identified research costs to the Amoco Cadiz oil spill. Because of the possibility that the total identifiable research costs either over- or under-estimated the appropriate amount to attribute to the Amoco Cadiz oil spill, no attempt was made to adjust the amounts. Thus, the total of 15.6 million francs in Table 6–1 is the unadjusted total of all the research costs that could be identified.

As shown in Table 6–1, the estimated expenditures on research were between 15 and 16 million francs. About 85 percent of the expenditures was for natural science research; economic studies accounted for about 15 percent of the total expenditures.

DAMAGES TO AGRICULTURAL CROPS

The Ministry of Agriculture confirmed that field crops near Roscoff were damaged by wind-borne mists during the height of the oil spill and were later plowed under to avoid health risks. The crops destroyed consisted mainly of green, leafy vegetables. Additional crops were damaged in the process of moving equipment into the oil spill zone.

Compensation was paid to the damaged farmers by the prefecture in Finistere from a special quasi-governmental fund. An inquiry was made into how officials distributed payments from this fund to claimants. It was concluded that valid claims for losses totaling 49 thousand francs had been paid. It is believed that this amount represents full compensation for the social costs of the damages to agricultural crops. Because the French

national government paid the compensation, the cost represents a cost to France and not to the region.

DAMAGES TO HUMAN HEALTH

The Amoco Cadiz oil spill directly exposed two groups of people: residents of the adjoining areas exposed to volatile hydrocarbons released into the air; and volunteer workers, military personnel, and other public employees, subjected to respiratory contamination, direct contact with their skin, and involuntary ingestion of small quantities of petroleum during the cleanup operation. There have been no other oil spills in which such exposures have been studied. Because of the lack of prior studies, the Amoco Cadiz oil spill presented both problems and opportunities. From the standpoint of studying the effects of oil spills on human health, the spill was problematic in that there was no analytical model to follow. At the same time, this lack of precedent offered the opportunity to undertake a program of investigation that could conceivably provide information about the effects of future oil spills on human health.

However, no coordinated formal study was undertaken and there was no central direction to the data collection efforts. On 4 April 1978, the Faculty of Medicine (Faculte de Medecine) at the Brest Naval Hospital was directed by the Prefect of Finistere to undertake research efforts, but was provided with no specific funds for that purpose. The Army refused the request of the Faculty of Medicine to be allowed to conduct physical examinations before military personnel were sent into the oil spill zone. Therefore, the evidence on effects that was collected came from posterior clinical examinations and laboratory tests, with one exception. A group of nine residents of Alsace was examined before and after working in the affected zone.

The information from clinical examinations came from two sources. First, local doctors in the area of the spill voluntarily sent to the Faculty of Medicine reports on the effects of hydrocarbon inhalation on local residents. Second, a department of the municipal hospital center of Brest, along with the Red Cross, began examining and treating workers at stations set up in the field on April 1st. Data were gathered on 400 individuals. Clinical disorders observed and reported included general lethargy; irritation of membranes in the nose and throat; stomach pains; nausea and vomiting; headaches; and trouble breathing. Workers in direct contact with the oil also experienced a burning sensation on their hands, eye inflammation, and flushed faces. Almost none of the patients suffered acute symptoms, and in all cases the symptoms disappeared rapidly. These clinical symptoms were similar to those found in studies done on workers who clean tankers and on addicts who inhale hydrocarbons (Menez, et al., no date).

The Faculty of Medicine had laboratory samples from two hundred individuals. From these a subsample was selected in an attempt to obtain a relatively homogeneous group to test for significant biochemical changes as a result of exposure to oil. No significant hematological effects were found, although there were some significant increases in levels of certain enzymes in muscle tissues. This type of effect was thought to be the result of the high activity level of those participating in the cleanup process. In none of the samples of the nine residents of Alsace tested before particpating in the cleanup activity and tested again 8 days later was there a significant change in any of the parameters (Menez, et al., no date).

Tests were also made to determine the effect of exposure to hydrocarbons on the respiratory systems of 37 persons who had been in contact with the oil spill for periods varying from a few hours to 35 days. All tests showed negative results. However, the sample was small and very heterogeneous. All attempts to gather a more adequate sample were thwarted by the authorities (Barthelemy, no date).

In spite of all the problems in data collection, the preponderance of the evidence—both from casual observations and from tests—was that there were no serious, adverse, short-term effects on human health from the oil spill. One observer noted that, in their attempts to get a homogeneous sample, the doctors conducting the biochemical studies may have inadvertently biased their results. For example, the sample excluded people less than 18 and more than 35 years old, persons with known heart or lung problems, and pregnant women. It is possible that the groups excluded from the study would be more likely to display significant biochemical reactions than those included. It is also true, however, that researchers need a relatively homogeneous sample in order to draw conclusions, particularly when no ex-ante tests have been made. Thus, the conclusion—that there were no significant, short-term, adverse health effects—applies only to those tests that were done using accepted scientific methods on the given sample of individuals.

Reports from local doctors over the next 9 months showed almost no increase in clinical symptoms during the remainder of 1978. One case of epilepsy was reported, the onset of which coincided with the period in which the air was filled with fumes. Another patient experienced severe difficulty breathing during the days of the spill and was later discovered to have lung cancer. The psychiatric hospital at Bohars reported 9 cases, the onset of which seemed to coincide with the spill. Six of these patients lived in the area affected by the spill; four had marine-related occupations. In six or seven of these nine cases, there was a history of previous psychiatric problems. In none of these cases was it possible to establish a direct cause-and-effect relationship. Because some part of any population is always experiencing severe illnesses, it is rather amazing that more such coincidental cases were not reported during the event.

Although there seem to have been no short-term adverse effects on human health, there remains the ques-

tion of long-term effects on local residents and clean-up workers from direct contact with the oil in both liquid and volatile states. Petroleum is known to contain compounds that may well be carcinogenic to man (Bingham, et al., 1979; Hamilton and Hardy, 1974). However, the compounds thought to be most carcinogenic are the polycyclic aromatic hydrocarbons that appear in *refined* products of petroleum (Bingham, et al., 1979), rather than in crude petroleum, which was the cargo carried by the Amoco Cadiz. The only studies found on the biological effects of crude petroleum had been done on animals. The results ranged from some incidence of skin cancer when natural crude petroleum was applied to the skin, to no such incidence (Bingham, et al., 1979; Holland, et al., 1979). Despite the lack of conclusive evidence on effects, the French government ordered the destruction of oysters and other seafood affected by the oil spill, to preclude possible long-term effects which might result from ingestion of contaminated food.

On the basis of the foregoing, it was concluded that both short-term and long-term damages to human health from the Amoco Cadiz oil spill were negligible.

SUMMARY

The estimated social costs for those categories discussed above are shown in Table 6–2. The estimated total is 179–216 million 1978 francs. The loss of the cargo of crude petroleum and the loss of the tanker itself are the two major losses, representing between 91 and 93 percent of the total, depending on the cost assigned to the loss of the vessel. Neither of these costs was incurred directly by the citizens of Brittany or France. Instead, these losses were distributed among the shareholders of the companies involved, including the insurance industry, or were passed on to their customers, or both. None of the other costs was directly incurred by the citizens of Brittany, because the three costs shown to France were paid by the national government directly, e.g., research costs, or by compensation, e.g., to farmers in Brittany. Thus, most of the social costs of the oil spill estimated in this chapter were borne outside of France.

Table 6–2.—Summary of Estimated Social Costs for Other Cost Categories, Amoco Cadiz Oil Spill.

Cost category	Costs to France (1978 FR x 10^6)	Costs to Rest of World (1978 FR x 10^6)	Costs to World (1978 FR x 10^6)
Value of lost cargo	a	100	100
Value of lost tanker	a	63-100	63-100
Legal costs	0.4[b]	n.a.[c]	0.4[b]
Research costs	4.6	11.0	15.6
Damages to agricultural crops	<0.1	0	<0.1
Damages to human health	Negligible	Negligible	Negligible
Totals	5 (1)[d]	174-211 (42-51)[d]	179-216 (43-52)[d]

[a] A small, unknown percentage of the costs to the rest of the world of these categories would technically be borne by France, via any change in cost of purchasing and transporting crude oil as a result of the Amoco Cadiz oil spill.

[b] Lower limit, based on the only specific information available.

[c] Not available.

[d] U.S. dollars x 10^6 at 4.18 francs per dollar.

NOTES

[1] The estimated cost of a new ship of a design similar to that of the Amoco Cadiz was based on discussions with various marine architects.

[2] Excess tanker capacity—particularly in terms of supertankers—in relation to the increase in oil prices, began to be significant in 1979–80, about a year after the Amoco Cadiz accident. If that excess capacity had existed in 1978, and given that a number of supertankers were scrapped in 1980 and 1981, then the best estimate of the social cost of the lost tanker would have been its value in the production of scrap.

[3] Several conference proceedings and governmental reports have been cited in previous chapters which report results from research supported with funds listed in this section. For example, see Hess (1978).

[4] In 1978 France and the United States formed an international joint commission to manage a natural science research program to investigate the fates and effects of the oil spilled from the Amoco Cadiz. This program was supported by a grant from Standard Oil of Indiana (Amoco). It is believed that additional, but unknown, sums were contributed by France and the United States to the work overseen by the international joint commission. Thus, the figure reported here is likely to be a lower bound.

REFERENCES

Barthelemy, L., no date: Explorations fonctionnelles respiratories pratiquees chez des personnes soumises a la pollution par les hydrocarbures, in *Consequences Medicales du Naufrage de l'Amoco-Cadiz sur la Population Cotiere et les Volontaires Civils.* Faculte de Medecine de Brest, Brest, France (unpublished manuscript).

Bingham, E., R.P. Trosset, and D. Warshawsky, 1979: Carcinogenic potential of petroleum hydrocarbons: a critical review of the literature, *Journal of Environmental Pathology and Toxicololgy,* 3, 1&2, 483–563.

Bonnieux, F., P. Dauce, and P. Rainelli, 1980: *Impact Socio-Economique de la Maree Noire Provenant de l'Amoco Cadiz.* Institut National de la Recherche Agronomique, Rennes, France, 248 pp.

Congar, R., 1980: personal communication, Universite de Bretagne Occidentale, Brest, France.

Flink, M., 1981: personal communication, Standard Oil of Indiana, Chicago, Illinois.

Hamilton, A., and H.L. Hardy, 1974: *Industrial Toxicology.* Publishing Sciences Group, Acton, Massachusetts, 3rd edition, 575 pp.

Hess, W.N., editor, 1978: *The Amoco Cadiz Oil Spill: A Preliminary Scientific Report.* NOAA/EPA Special Report, National Oceanic and Atmospheric Administration, Boulder, Colorado, 349 pp.

Holland, J.M., R.O. Rahn, L.H. Smith, B.R. Clark, S.S. Chang, and T.J. Stephens, 1979: Skin carcinogenicity of synthetic and natural petroleum. *Journal of Occupational Medicine,* 21, 9, 614–618.

Kiechell, W., III, 1979: The admiralty case of the century. *Fortune,* 99, 8, 78–89.

Menez, J.F., F. Berthou, D. Picart, and C. Riche, no date: Impacts en biologie humaine de la maree noire (Amoco Cadiz), in *Consequences Medicales du Naufrage de l' Amoco Cadiz sur la Population Cotiere et les Volontaires Civils.* Faculte de Medecine de Brest, Brest, France (unpublished manuscript).

Chapter 7

DISTRIBUTION OF COSTS TO BRITTANY, FRANCE, AND THE REST OF THE WORLD

Thomas A. Grigalunas

INTRODUCTION

This chapter examines some of the distributional consequences of the Amoco Cadiz oil spill. Distributional effects—the incidence of gains and losses among individuals and groups of individuals—are important both politically and legally. The political consequences of events such as the Amoco Cadiz oil spill usually depend in large part on the pattern of losses and the claims of damaged parties. The ultimate political consequences often include new legislation and regulations. For example, with respect to the laws governing compensation from spills, the new (1980) "Superfund" of the United States provides for compensation to public entities for damages to natural resources resulting from spills of hazardous materials. Tort law and common law throughout the world often permit victims of events such as oil spills to gain compensation for damage to personal property and livelihood.

Distributional effects are both subtle and complex. This chapter presents an analysis of these effects for four political/economic aggregates: Brittany, France, the rest of the world, and the world. For these four aggregates, losses are estimated for the activities that were the foci of the analyses in Chapters 2 through 6: cleanup; marine resources; recreation, including tourists and residents of Brittany; the tourist industry; and other. The focus of this chapter is on aggregates. No attempt was made to identify the magnitudes of losses to particular individuals. Such an inquiry, while valuable, was simply beyond the scope of this study.

The results of the analysis in this chapter illustrate three essential points. First, the estimate of social costs to Brittany, net of compensation payments from elsewhere in France (and from outside of France), indicates how much of the economic burden of the spill was borne in Brittany. Second, the estimate of total social costs to France is indicative of the level of compensation to the French state that could be justified on economic grounds. Finally, the estimate of distributional effects among Brittany, France, and the rest of the world illustrates how losses can vary widely, depending upon the boundaries that are chosen for the analysis. For example, losses to the tourist industry in the physically affected zones of Brittany are substantially different from the losses to the tourist industry in the rest of France. Thus, the chapter should serve as a reminder to those who contemplate compensating victims, that measurement of losses to individuals requires detailed information on individual activities. Allocation of compensation through shares of estimated aggregate effects would be subject to large and unpredictable errors.

There is also a conceptual difference between regional costs and costs to the nation or costs to the rest of the world. The remainder of this section defines the concept of regional costs. The second section describes the methodology and data used in the analysis of regional costs and presents the results of that analysis. Most of the estimates of regional costs are taken directly from the cost estimates presented in the preceding chapters, although it is necessary to make some additional estimates of some components of regional costs. The third section contains a summary of the distribution of the costs of the Amoco Cadiz oil spill to Brittany, to France, to the rest of the world, and to the world.

Definition of Regional Costs

Regional costs are those borne by residents of Brittany. A loss in tourism profits in Brittany, for example, is a cost to the region, but not necessarily a cost to France, if offset by an increase in tourism profits elsewhere within the country. Similarly, a net loss in local public revenues is a cost to the region, but not to the nation, if counterbalanced by an increase in such revenues elsewhere within France. A loss in a resident's consumer surplus because of a perceived reduction in beach quality or the higher cost of going to a substitute site is a regional cost; but if the individual is from outside Brittany, the loss in consumer surplus is a cost to France or to the rest of the world and not to the region. Simarly, a loss in tourism producer profits is a cost to the region when the tourist facilities are owned by residents of the region. If ownership is from outside the region, the loss is not a regional cost.

It is apparent from the above that not all regional costs are necessarily national or rest-of-the-world costs, and vice versa. The regional focus involves drawing an

economic boundary around Brittany. Only those costs incurred by residents of the region are counted as regional costs; all other costs are ignored. In principle, the magnitude of the regional costs, if they could be measured accurately, can be viewed as the amount that residents of the region would have to be paid in order to be no worse off in economic terms following the oil spill than they were before the spill.

The cost of the Amoco Cadiz oil spill to residents of the region can be stated as follows:

$$RC = RCC + LPW + LRCS + NFE + RSE, \quad (7\text{–}1)$$

where RC = cost to the residents of Brittany;
RCC = emergency response, cleanup, and restoration costs borne by the region;
LPW = net loss in regional profits and labor earnings in tourism, fishing, and aquaculture;
$LRCS$ = lost recreational consumer surplus by residents of the region;
NFE = net regional fiscal effects; and
RSE = regional secondary economic effects.

METHODOLOGY AND DATA FOR, AND RESULTS OF, ESTIMATING AND ALLOCATING COSTS

The preceding section has defined regional costs and has identified each of the components of total regional costs. The realities of data limitations strongly influenced the choice of procedures used to estimate some components of regional costs. This section describes the procedures used and presents the results for each cost component. The basis for the global estimate of each cost component has been set forth in detail in earlier chapters. The present section emphasizes those aspects of the analysis that concern regional costs, as distinct from national and rest-of-the-world costs.

Regional Cleanup Costs

In economic terms, regional cleanup costs equal the opportunity costs of the regional resources used to clean up the spilled oil less net transfers to the region to finance the cleanup effort. Opportunity costs measure the real costs of cleaning up an oil spill because they indicate the value of outputs forgone when resources are diverted from alternative productive activities.

A region incurs a direct cost if the opportunity costs of regional resources used and any taxes paid to the national government on cleanup-related purchases are not fully compensated by payments from outside the region. A region also bears some of the cleanup costs indirectly, to the degree that residents of the region pay a portion of the national expenditures on cleanup, e.g., through additional personal income and business taxes paid to, and/or reduced public services provided by, the national government.

The analysis of cleanup costs in Chapter 2 concluded that the region was compensated by the national government for virtually all of the costs incurred to clean up the spill. Thus, direct regional costs were estimated to be zero. Compensation was based on submittal of invoices which included value-added taxes. As far as could be ascertained, compensation payments from the national government to individuals and entities in the region approximately equaled opportunity costs to the region plus the value-added taxes paid by the region. These compensation payments for cleanup costs made to the region involved flows of payments between France and the region. Accounting for such payments required unraveling the complex set of financial payments that followed the oil spill. There were two major problems in estimating compensation payments. One, not all of the details of the transactions were public information, yet double counting had to be avoided. Two, the determination of liability for damages had not been settled at the time the analysis was made, so that the issue of the *ultimate* financial incidence of the cleanup costs could not be assessed completely.

As noted, the region indirectly bears a portion of national cleanup costs to the extent that public services provided by the national government to the region are reduced and/or additional taxes are paid by the region to the national government to help finance cleanup, including compensation payments. One portion of the cleanup costs incurred by France in connection with the Amoco Cadiz oil spill was the cost of diverting ships and military personnel and equipment from alternative activities, as was described in Chapter 2. The services provided by these resources are public goods, and the value forgone is a cost shared by Brittany with other French regions. It is doubtful that national taxes were increased because of cleanup costs, both because a large share of the national costs was in the form of payment in kind, and the remaining cost is small relative to the national budget. For simplicity, it is assumed that the region's share of national cleanup costs can be reasonably measured by the share of the national budget funded by taxes from the region. The Institut National de la Statistique et des Etudes Economiques (1979) estimated this share as 2.7 percent, but current research by Prud'homme suggests that this share is more likely to be between 3.5 and 4.2 percent.[1] This range is used in subsequent calculations.

National cleanup costs were estimated in Chapter 2 to range from 430 million to 475 million francs.[2] Applying the region's tax share specified in the preceding paragraph yields a range of cleanup costs borne by Brittany of 15 million francs, 0.035×430, to 20 million francs, 0.042×475. The *ultimate* distribution of cleanup costs between France and the rest of the world depends upon the resolution of claims concerning liability for costs resulting from the oil spill.

Regional Marine Resources Costs

Quantitative estimates of costs in this category were made for losses of existing stocks and of expected outputs in oyster culturing and other aquaculture operations, holding operations for shell fisheries, and open-seas fisheries; damages to marine sand and gravel operations; and damages to, and losses in value of, real property. The results reported in this section are adapted from Chapter 3.

The total costs to marine resources were estimated to be 140 million francs. The largest cost in this category was for the oyster-culturing industry, about 107 million francs. The major shares of this total are for the loss of expected production over the years 1978–1981 and the wholesale value of the oyster and mussel stocks destroyed or made unmarketable by the oil spill.

The net social cost to open-sea fisheries was estimated to be about 20 million francs. The net social cost figure is based on the estimated reduction in the ex-vessel (dockside) value of landings, less the costs saved because of reduced fishing effort. The net social cost also includes an allowance for under-reporting by fishermen, assumed to be 20 percent of the recorded values.

The remaining major cost in this category comprises damages suffered by the holding tank operations for shellfish, mainly lobster, about 11 million francs. The principal components include loss of expected income because of reduced sales in 1978–79; the costs of restoring holding tanks, seawalls, and grounds; and extraordinary costs of advertising and promotion.

Other costs to marine resources include about 1 million francs damage each to fishing boats and equipment and to real and personal property; about 0.1 million francs damage to marine sand and gravel operations; and less than 0.1 million francs in damage to each of the categories of marine aquaculture and seaweed harvesting and processing.

Virtually all of the costs to marine resources were paid by the national government in the form of compensation to the affected individuals and entities. Only about 1.5 million francs of costs in terms of damage to fishing boats, fishing equipment, and real and personal property were borne directly by the region.

However, as indicated in the previous section, the residents of Brittany were estimated to contribute between 3.5 and 4.2 percent of the revenues collected by the national government. Applying these percentages to the estimated compensation payments yields costs to the region of about 4.8 million and 5.8 million francs. Therefore, total costs related to marine resources borne by the region are estimated to be 6–7 million francs.

Regional Recreation: Tourist and Residents

Three categories of social costs relating to recreation were identified: (1) losses to tourists who had planned to go in 1978 to the Brittany shore in the oil spill zone, but did not go; (2) losses to tourists who came in spite of the spill and suffered some reduction in satisfaction because they changed their planned recreation activities as a result of the spill; and (3) losses in satisfaction by residents of Brittany who changed their recreational behavior patterns as a result of the spill. Chapter 4 described in detail the one method used to estimate the losses for the first category; the two basic methods used to estimate the losses for the second category; and the one method used to estimate the losses for the third category. Because of the two methods in the second category and their variations, and because of the two alternative assumptions used in relation to the third category, there is a wide range in the estimated total losses, i.e., about 50 million francs to about 340 million francs.

The distribution of losses among Brittany, France, and the rest of the world, was based on estimates of the origins of the visitors in the above three categories. Given the origins and the categories, the distribution of losses was estimated by applying the relevant unit loss figures to the estimated numbers in each category. Costs to Brittany ranged from 3 million to 53 million francs; to France from 31 million to 290 million francs; and to the rest of the world from 22 million francs to 52 million francs.

The Regional Tourist Industry

Three approaches were used to estimate losses to the Brittany tourist industry. These approaches were explained in detail in Chapter 5. The first approach—the results of which were ultimately used—was based on the estimate in Chapter 4 that about 245 thousand visitors did not come to Brittany in 1978, as a result of the oil spill. This information was used with data on average expenditures by tourists from a 1979 INSEE survey to arrive at the decrease in tourism-related expenditures in 1978 as a result of the Amoco Cadiz oil spill. The estimated decrease in Brittany visitor expenditures in 1978, using this approach, was about 240 million francs. The estimated economic loss associated with these decreased expenditures was about 115 million francs. An additional loss of about 1 million francs was incurred because of a reduction in expenditures on ferry services of the region.

The total loss of 116 million francs was apportioned in Chapter 5 as follows:

to Brittany, 116 to 110 million francs;
to France, 29 million francs; and
to the rest of the world, 29 million francs (gain).

The apportionment was based on (1) an estimate that between 0 percent and 5 percent of the tourist industry in Brittany is owned outside Brittany; (2) the fact that many of the tourist industry services which would have been provided by the tourist industry in Brittany, if the spill had not occurred, were provided by the tourist in-

dustry elsewhere in France; and (3) the fact that the net losses to the tourist industry in France represented an equivalent gain for the tourist industry outside of France.

Other Regional Costs

As discussed in Chapter 6, other costs analyzed included the values of the lost cargo and the lost vessel at the time of the accident; legal costs; expenditures on research related to the oil spill; damages to agricultural crops; and damages to human health. The last two categories incurred negligible costs. The value of the lost cargo was estimated to be 100 million francs and the value of the lost tanker was estimated to be 63–100 million francs. Legal costs were estimated to be a minimum of 0.4 million francs. Research costs were estimated to be 4.6 million francs.

The legal costs and about one-third of the research costs, totaling about 5 million francs, were borne by France. The remainder of the costs identified above, 174–211 million francs, were borne by the rest of the world. None of the estimated costs was borne by Brittany.[3]

Net Regional Fiscal Effects

The residents of a region affected by an oil spill bear an economic cost if the spill imposes a net fiscal loss on the region. That is, the region can be said to have suffered a net fiscal loss if the loss in public revenues from all sources is greater than the reduced opportunity cost of all regional government expenditures impacted by the oil spill, except for cleanup costs, which are accounted for elsewhere. A net fiscal loss implies that either reduced public services would be available to residents if the budget is fixed, or—for a given level of services—additional taxes and fees would be necessary. In either case, the residents of an area suffer a loss in welfare.

In the United States, the Outer Continental Shelf Lands Act Amendments of 1978 (OCSLAA) recognized the potential fiscal costs that can be incurred by a region as a result of an oil spill from offshore oil and gas exploration and production activities. The Offshore Oil Spill Pollution Fund, established as Title III of the OSCLAA, provides that local governments affected by an offshore oil-related spill can collect from the national government lost revenues for a 1-year period.

To gain some insight into the impact of the Amoco Cadiz oil spill on local public revenues, a preliminary analysis was made of commune budgets in the oil spill area for 1977 and 1978. The purpose of the preliminary analysis was to assess the potential significance of fiscal effects, and hence to assess the need for a more extensive study of this category of regional costs.

The communes considered were those along the coast in Finistere and Cotes-du-Nord affected by the oil spill. Attention was directed toward those revenues and fees judged to be most sensitive to changes in the level of local tourist activity. Thus, if one were to find anywhere in Brittany a decline in local public revenues as a consequence of the Amoco Cadiz oil spill, it would be for the communes considered, because their beaches were directly affected by the oil and the resulting unfavorable publicity.

The following commune taxes and fees were considered:

1. revenue from municipal parking (droits de place de voirie et de stationnement);
2. revenue from municipal campgrounds (produits des campings municipaux);
3. revenue from the rental of buildings and machinery (produits obtenus de la location des immeubles et du materiel des communes); and
4. tax on the use of electricity (taxe sur l'energie electrique).

The last applies only to communes in Finistere.

In Brittany, there are no locally collected taxes on hotel revenues or on meals and liquor sales in cafes and restaurants, and the vast share of all taxes paid in France accrue to the national government.[4] Taxes are levied on land and real estate at the commune level. However, the investigation of the possible influence of the Amoco Cadiz oil spill on real property values described in Chapter 3 produced no evidence that property values had been affected by the spill. Moreover, even if the market value of property had been affected, assessed values are insensitive to changes in market values. For these reasons, revenues from land and property taxes were not considered.[5]

The budgets for 50 communes were examined. The analysis of these budgets showed a decrease of about 250 thousand francs in taxes and fees between 1977 and 1978. This amount represented a decrease of 7 percent in the public revenues received from the sources indicated above in 1977. If tourism-related public revenues and fees had increased between 1977 and 1978 at a rate consistent with the results of the models of the tourist industry in Brittany, i.e., about 8 percent, then the loss in commune public revenues in the polluted zone would have amounted to about 520 thousand francs.

The decline of 7 percent in total tourism-related public revenues for the communes physically affected by oil from the Amoco Cadiz appeared reasonable, but the results by subcategories were ambiguous in several respects. For example, although revenues from municipal parking in Cotes-du-Nord fell in 1978, revenues for municipal campgrounds actually increased by 20 percent. In fact, the total of tourism-related revenues for this department grew by 7 percent between 1977 and 1978. This percentage is almost equal to the predicted 8 percent increase, thus suggesting that the oil spill had only a very small effect.

In summary, the analysis indicated that the communes along the polluted zone possibly suffered a decline of between 250 and 520 thousand francs in tourism-related public revenues between 1977 and 1978. Because

the revenues considered accounted for less than 5 percent of commune budgets, the overall impact of the Amoco Cadiz oil spill on total commune revenues appeared to have been negligible. It should be emphasized, however, that only revenues were considered. The estimate does not include any possible reductions in local public service costs because of the decline in the number of tourists in 1978. More significantly, it did not include any cleanup costs incurred by the communes. Because the fiscal effects considered were so small, further analysis was unwarranted.

One last point should be mentioned. A detailed analysis of local fiscal effects is not a useful exercise in France, because the tax system channels such a large share of receipts to the central government. However, a study of the effects of a large oil spill on regional public revenues in countries with tax structures similar to those in the United States could be very useful, because of the importance of sales, room, and meal taxes to states and other governmental units.

Secondary Effects on Regional Income

Secondary effects refer to the indirect or general equilibrium changes in regional income that result from a change in demand for the output of a regional industry. Environmental incidents such as the Amoco Cadiz oil spill can result in indirect effects within a region. For example, if a spill reduces the demand for finfish or shellfish, or for hotel, restaurant, and other services and supplies, then the reduced *derived* demands for inputs to those industries will cause an indirect loss in regional income, if resources are thereby made idle or earn less. Indirect losses in regional income also can occur in forward markets, for example, if reduced fish landings because of a spill lead to unemployed resources at processors, canners, or wholesale and retail facilities because no substitute fish products are available.

On the other hand, secondary increases in regional income can result from demands imposed on regional industries as part of the cleanup effort. However, if secondary increases in income resulting from regional resources used for cleanup activities are included, then logically secondary losses of income resulting from the diversion of these resources from alternative activities must also be included. Unless there are demonstrable differences in the pattern of indirect resource demands and their unemployment and capacity utilization rates between the alternative activities, there is no basis for assuming that there is a *net* difference in secondary effects.

It is emphasized that secondary effects normally are a regional, and not a national, phenomenon. Secondary changes in income in one region usually will be offset by secondary effects in other regions and cancel out from the point of view of the nation as a whole. In theory, regions realizing a net gain could compensate the region suffering a net loss. In reality such compensation is likely to be partial at best, and depends upon the prevailing policies and laws regarding indemnities and compensation.

In practice it often will be difficult to measure secondary regional economic damages, particularly where affected businesses are located some distance from the spill area or where the effect of the spill on an enterprise is small. Moreover, the problem remains of attributing a decline in demand to the spill rather than to other causes, such as poor weather or unfavorable economic conditions.

The estimation of secondary regional effects in this study consisted of a two-step procedure. First, the direct economic effects of cleanup, and of changes in such activities as marine resources exploitation and the tourist industry, were estimated. These direct economic effects have been detailed in the preceding section. The second step involved the application of a multiplier from a regional economic model to estimate the secondary economic effects on the region.

Cleanup Costs

Secondary increases in regional income can result from demands on regional resources as part of cleanup operations. The approach adopted here is to apply a regional multiplier to the estimate of regional cleanup costs made earlier. The multiplier used is 0.68, the multiplier for the construction–public-works sector in Brittany in what is herein referred to as the CREFE model.[6] This sector corresponds most closely with the nature of the cleanup activity. The multiplier of 0.68 means that there will be a 0.68 franc direct and secondary change in regional income across all regional industries for each franc change in demand for the output of the construction–public-works sector. The direct effect alone is 0.52 franc; that is, a 1-franc change in output in this industry is associated with a change of 0.52 franc in regional income in this industry by means of the coefficients in the input-output table of the Brittany economy.

Using the above figures, the direct and secondary change in regional income as a result of cleanup operations, net of compensation payments, ranges from about 10 million francs (0.68×15) to about 14 million francs (0.68×20). The secondary effect alone ranges from about 2 million francs to about 3 million francs.

Marine Resources

The social costs of the oil spill to open-seas fisheries, oyster-culturing operations, and viviers of shellfish (mostly lobster), were estimated to be about 20 million, about 107 million, and about 11 million francs, respectively. A potential for secondary losses in income to suppliers in the region of inputs to these activities exists in the short run, if the purchases of inputs are reduced because of lower levels of effort.

The study of the response of Brittany fishermen to the Amoco Cadiz oil spill found that there was a significant decline in fishing effort in 1978 in the quartier maritime of Paimpol immediately following the oil spill, but

there was a significant increase in the quartier maritime of Morlaix. Because the two efforts appeared to be largely offsetting the secondary effects for activities relating to marine resources were considered negligible.

Tourist Industry

The secondary effects resulting from the change in tourism activity in Brittany during 1978 were estimated by use of the previously cited input-output model of the Brittany economy. The secondary effects were estimated using the ratio of direct and secondary income effects to direct income effects for regional tourism-related industries in the CREFE model. This ratio is 1.2, and is equivalent to the Type I income multiplier used in regional economic studies (Miernyk, 1969). The interpretation of this multiplier is that there will be a 0.2-franc secondary change in income in all regional industries supporting the tourist industry for each franc direct change in income in the tourist industry resulting from a change in demand for the tourism goods and services of the region.

The above multiplier was applied to the reduction in demand for the goods and services provided by the Brittany tourist industry, estimated to be about 116 million francs. The result was an estimate of secondary losses in regional income related to the tourist industry of about 23 million francs.

Net Regional Fiscal Effects

Secondary effects are also associated with local fiscal effects. The reduction in public revenues of 250–520 thousand francs can be viewed as a reduction in demand for local public services by summer visitors who did not come to the region. Using the multiplier of 0.84 for the service sector in the CREFE input-output table as a proxy for local government, the direct and secondary effects on regional income were estimated to be about 210–440 thousand francs, i.e., 250×0.84, and 520×0.84. The secondary effect alone would be about 40–80 thousand francs, a negligible quantity.

Summary of Secondary Effects

The secondary effects on regional income were estimated to be about 25–26 million 1978 francs, as indicated in Table 7–1. Secondary effects are so small for three categories—marine resources, other activities, and local fiscal effects—as to be negligible.

ESTIMATED DISTRIBUTION OF SOCIAL COSTS OF AMOCO CADIZ OIL SPILL AMONG BRITTANY, FRANCE, AND THE REST OF THE WORLD

Based on the analyses described above and the details reported in previous chapters, the derived distribution of the estimated social costs of the Amoco Cadiz oil spill is shown in Table 7–2. In relation to total net social costs (to the world), emergency response/cleanup/restoration comprised the largest single cost component, followed by losses in satisfaction of recreationists, losses to the oyster-culturing industry, loss of cargo, and loss of tanker.

The distribution shown in Table 7–2 merits the following comments. One, essentially all of the expenditures made for cleanup in Brittany and virtually all of the damages to marine resources in Brittany were borne by the French national government, through direct expenditures and through compensation payments. However, it must be emphasized that there are likely to have been both some costs for which no data were available and for which no compensation was paid to Brittany. The amount is believed by the analysts to be small, i.e., less than 5% of the sum of the regional costs of the cleanup and marine resources categories.

Further, it is difficult to account unambiguously for the transfer payments, as noted previously, because many

Table 7–1.—Summary of Regional Secondary Economic Effects of Amoco Cadiz Oil Spill on the Brittany Region.

Secondary Economic Effects Related to:	Costs (1978 FR x 10^6)
Cleanup costs	2-3
Marine resources	negligible
Tourist industry	23
Other activities	negligible
Net regional fiscal effects	negligible
TOTAL	25-26

Table 7-2.—Distribution of Estimated Social Costs of the Amoco Cadiz Oil Spill.

Category of Costs	COSTS INCURRRED (1978 FR x 10^6)[a]			
	Brittany (1)	France, Including Brittany (2)	Rest of the World (3)	Total Net Social Costs to World (2) + (3)
Cleanup	15-20[b]	430-475[b]	15	445-490[b] (106-117)
Marine resources	6-7	140	0	140 (33)
Recreation: tourists and residents[c]	3-53	31-290	22-52	53-342 (13-82)
Tourist industry	110-116[d]	29[e]	- 29[e]	0[e]
Other[f]	0	5	174-211	179-216 (43-52)
Regional secondary effects	25-26	-	-	-
TOTALS	159-222 (38-53)	635-939 (152-225)	182-249 (42-60)	817-1188 (195-284)

[a] U.S. dollars at 4.18 francs per dollar. Dollar amounts are in parentheses.

[b] The range reflects the two alternative assumptions about the residual value of capital equipment purchased.

[c] The range reflects the various methods for estimating the losses in satisfaction of tourists who did come in 1978 and of residents.

[d] The range reflects the two alternative assumptions about the proportion of tourist industry businesses in Brittany owned outside Brittany, i.e., 0 and 5 percent.

[e] The figures are based on the assumption that three-fourths of the losses to the tourist industry in Brittany was recouped by the tourist industry elsewhere in France; the other one-fourth represented a gain to the tourist industry outside France, in effect, a net gain for the "rest of the world." Thus, the net social costs to the world with respect to the tourist industry are essentially zero.

[f] Other includes values of lost cargo and tanker, legal costs, research costs,

of the data were, and are, not public. As far as could be ascertained, virtually all of the payments indicated were in fact made to the region by the national government. In the absence of compensation payments, the burden of the costs associated with cleanup and losses to marine resources would have fallen heavily on the region. As it was, the residents of Brittany bore basically that portion of those costs in proportion to their tax payments to the national government.

Two, as noted at various places in the previous chapters, some costs were incurred in years subsequent to the year of the spill. Not all of these subsequent costs could be accounted for in the analyses. This is particularly true with respect to possible long-run damages to certain marine resources, such as oyster culturing. However, these costs would represent a small portion of the total costs identified, and are well within the accuracy of the estimated costs.

Three, losses to the tourist industry constituted the major social cost to Brittany. Losses in tourism profits and labor earnings were considerably less important for France as a whole. This fact follows from the high probability that most of the summer visitors who avoided Brittany's beaches in 1978 because of the perceived effects of the oil spill spent their vacations elsewhere in France. It follows that the secondary economic effects of the spill, which are mostly attributable to the tourist industry, were much smaller—probably negligible—for France than for Brittany, because the secondary losses to the region's tourist industry were offset by increases in the tourist industry in other regions of France.

Four, because it appeared likely that tourists who did not go to Brittany or to other areas in France in 1978 did go somewhere for recreation that year, the net social cost to the world with respect to the tourist industry was estimated to be essentially zero.

Five, the wide range in the estimates of losses in satisfaction (welfare) to recreationists reflects the limited data available for analysis, very small sample sizes, and the unfamiliarity of Europeans with hypothetical survey questions.

The total net social costs of the Amoco Cadiz oil spill were estimated to be between about 800 million 1978 francs and about 1,200 million 1978 francs. The analysts are reasonably confident that the net social costs of the oil spill amounted to one billion 1978 francs plus or minus 20 percent (800–1,200 million francs), or approximately 190–290 million 1978 dollars.

NOTES

[1] Remy Prud'homme, an economist at the University of Paris, in a personal communication to the author dated April 6, 1981, indicated that an estimate of 2.7 percent probably understates the share of national revenues contributed by Brittany. The reason for this is that the relevant INSEE statistics are allocated to the region in which the corporations are registered, which tends to overstate the share of national taxes "collected from" the Paris region and to understate the tax contribution of other regions because many companies have headquarters in Paris. Prud'homme's preliminary findings, based on ongoing research, suggest that Brittany's share of the total national taxes raised in France may be between 3.5 percent and 4.2 percent.

[2] A very small portion of the cleanup costs was covered by gifts from outside France, gifts made to the French national government and to various entities in the region. A public record of early gifts made to France to assist in the cleanup/restoration efforts following the oil spill is in the proceedings of the 1978 inquiry of the French Senate Commission on the Amoco Cadiz oil spill. The best estimate of the amount is about 2 million 1978 francs. This amount was so small, and the information with respect to recipients so unclear, that it was ignored in the tabulations.

[3] To be conceptually consistent, Brittany would bear the share of French research and legal costs represented by its contribution to national revenues, i.e., 3.5 percent to 4.2 percent. Given these percentages, the amount would be on the order of 200 thousand francs.

[4] See Dubois (1977) and Gambier (1979).

[5] The professional tax imposed on business enterprises and based on wages paid, the capital of the enterprise, and—for some small businesses—on sales, is a source of local revenue. Data were wholly inadequate to permit isolating the effect of the Amoco Cadiz oil spill on receipts from the professional tax. To the extent that the communes may have suffered a decline in revenue from this source, the estimate of local fiscal effects understates regional costs.

[6] The model is described in Mandart, Krier, and Kergoat (1976). All subsequent citations of coefficients and multipliers are from this study.

REFERENCES

Dubois, M., 1977: *L'Enterprise et ses Impots,* Dunod Enterprise, Paris.

Gambier, C., 1979: *Les Impots en France,* Frances Lefebvre, 11th edition, Paris.

Institut National de la Statistique et des Etudes Economique, 1979: Statistiques et Indicateurs des Regions Francaises, Annexe au Project de Loi de Finances pour 1979. No. 298–299 des Collections de l'INSEE, serie R, No. 34–35.

Mandart, C., H. Krier, and J. Kergoat, 1976: Les relations entre la Bretagne et l'exterieur: le tableau d'ensemble des ressources et des emplois regionaux de biens, in *Le Tableau Economique de la Bretagne,* Bulletin de Conjoncture Regionale—Region de Bretagne, No. 3, Centre Regional d'Etudes et de Formation Economiques, Rennes, France, pp. 115–149.

Miernyk, W.H., 1969: *The Elements of Input-Output Analysis,* Random House, New York.